Evaluation of timber floor systems for fire resistance and other performance requirements

by

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Fire Engineering Research Report 10/1
2010

A project submitted in partial fulfilment of the requirements for the degree of Master of Engineering in Fire Engineering

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Abstract

Timber is a traditional building material used for floor construction in historic buildings and is widely used today in domestic and residential construction. There is increased interest in timber for long span floor systems in commercial and multi-storey residential applications. A major reason for this interest is timbers high strength-to-weight ratio, and when used in floors, can lead to significantly lighter buildings. These resulting weight savings allow for smaller foundations and less lateral load applied to seismic-resisting structural systems.

New timber and timber-concrete composite floor systems have emerged to provide increased span lengths. These longer span timber floors are typically achieved with deep solid timber joists of laminated veneer lumber or glulam, solid timber laminated deck plates and timber-concrete composite floor systems. There are several engineered timber floor joist and timber floor truss products already available in Australasia. New floor systems recently introduced into the market include Potius stressed-skin floors and Flexus floor, both of which are prefabricated into floor panels off site.

The timber-concrete composite floor system utilises the compressive strength of concrete and the tensile strength of timber. The composite concrete topping adds weight to the floor system, however this is offset by structural, fire and acoustic benefits. Currently there is ongoing study of timber-concrete composite floor systems at the University of Canterbury in Christchurch, and stressed-skin floor systems at the University of Technology in Sydney, so that these longer span floor systems can be used for building design in the near future.

Gypsum board ceilings are typically installed beneath timber floor systems to provide an enclosed space for distribution of building services behind a visibly uniform finish. A gypsum board ceiling can also provide fire resistance and acoustic performance and the information for these aspects is readily available. Alternatively, some floor systems allow exposed timber joists or timber surfaces. In these situations, fire resistance and acoustic performance are specifically designed.

Acknowledgements

I would like to thank my supervisor Professor Andy Buchanan, whose inspiration and encouragement has helped me to complete this phase of my studies as well as my co-supervisor Hans Gerlich, for his assistance and understanding of what I was trying to achieve in this report. Thanks again to Professor Andy Buchanan, along with Associate Professor Charley Fleischmann and Dr Mike Spearpoint, who have provided an enjoyable and extremely challenging masters course that caters equally for distance and local students.

There are many others associated with the University of Canterbury that I would like to thank for their assistance: Christine McKee, Engineering Information Librarian who helped source various documents for this report. Dr Peter Moss and Dr Jeremy Chang, for their advice regarding SAFIR thermal modelling. James O'Neill and Dr David Carradine, for allowing me to observe the timber-concrete composite floor fire tests at BRANZ. Dr Stefano Pampanin, Dr Bruce Deam, Dr Massimo Fragiacomo and Michael Newcombe, for passing on their enthusiasm for timber engineering. David Yeoh, Dr Jeff Mann, and Nicolas Perez, for their specialist advice. All of my fellow MEFE classmates, part-time and full-time students, who I met and studied with on various block courses over the past four years.

Thank you to Gavin Robertson of Potius, Andy Van Houtte of Nelson Pine and Jason Guiver of Hunter Laminates, who extended a warm welcome during my visit to Nelson and shared their knowledge of timber product manufacturing. Thank you to Carl Devereux, Paul Martini, Fiona Parr, all of Aurecon, who provided preliminary information regarding structural, fire and acoustics on the NMIT building. Thank you to Professor Keith Crews, Dr Chris Gerber and Zhinous Zabihi of UTS for their input into stress-laminated timber, stressed-skin panel plywood box beam floor systems.

Finally, I would like to thank my wonderful wife Jane and fantastic children Connor and Bridget. I am especially grateful to them for their understanding and support when time has been spent on work and study instead of with them. I look forward to the future opportunities and challenges that these acquired skills have prepared me for, and especially look forward to more quality time with my family and friends.

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1. Introduction

This chapter describes the background of this research and defines the scope and objectives. Current timber research initiatives are also presented.

1.1 Caveat

The contents of this report regarding timber and timber-concrete composite floors are only intended as a guide. Original sources of information should be consulted for actual design of specific projects using timber and timber-concrete composite floors to ensure the designer has complete, current and accurate data to incorporate all requisite design features, technical information, arrangement details and manufacturer's recommendations.

1.2 Background

This project summarises the design performance of several timber and timber-concrete composite floor system through research and evaluation of existing and proposed systems in New Zealand as well as overseas developments. Information was sourced from manufacturers and published documents to include systems currently tested in New Zealand and overseas. Other aspects addressed include floor span capability, long term deflection performance, vibration effects, thermal mass for temperature retention to reduce heating and cooling requirements and diaphragm action of floor systems for transmission of floor loads into frames to resist lateral loads. Some comparisons are made with alternative material systems such as precast concrete systems, lightweight steel joist systems and steel tray with concrete systems.

Floors are an integral part of building systems. Their primary function is to carry vertical loads, fixed and transient. Fixed gravity loads include the self-weight of the floor system, floor coverings, ceilings, insulation and walls partitions. Moveable live loads include storage, furniture and people, and applicable load depends on the occupancy and intended activities. At present, there is a significant amount of investigation into timber-concrete composite floor systems in particular, as this system can improve strength, stiffness, fire resistance, acoustics and vibration characteristics. It also offers the potential to utilise the thermal mass of the concrete component and the aesthetics of the timber.

The structural design aspects of typical timber floor systems are well known and can be reliably calculated. Span capacity, deflection and vibration are determined for the applied loads. Calculations for capacity and deflection are relatively easy, while quantifying vibration characteristics is more complex. Diaphragm action is the floors ability to transmit forces based on in-plane stiffness of the floor. The importance of diaphragms increases as the floor spans widen and with increased number of stories in a building. Timber only floor systems result in diaphragms that are more flexible than those with concrete topping.

Beyond the structural function, floors provide other important roles including fire separation and acoustic insulation between adjacent floor levels. Floor elements can provide continuous horizontal compartmentation to separate building levels from vertical fire travel and vertical noise travel. The acoustic performance is a key factor, and there is a closely linked relationship between the fire and acoustic parameters to be explored. For simple timber joist floors, fire resistance and acoustic performance are both typically achieved with gypsum board ceilings, either directly to the joists or suspended to create an increased air gap. The fire and acoustic solutions are detailed separately, while still including information on the other, although the associated rating is minimal.

The building codes provide significant emphasis on the outer wall envelope for thermal efficiency. Floors often comprise a large proportion of the surface area within a building, that could provide thermal mass to allow greater stability of the internal environment. The influence of floors on energy efficiency is primarily a function of the thermal mass makeup of the floor and the exposure of the thermal mass surface to utilise this advantage.

There are several emerging engineered products and design solutions for timber and timber-composite floor systems. These timber systems are being developed with increased span capacity to compete in the commercial building sector with more traditional concrete and steel-concrete floor systems. To gain acceptance in the market, timber and timber-composite floor systems must also achieve applicable levels of performance for fire and acoustics. Other aspects including thermal mass, constructability and economics are also identified.

A new timber floor system has been designed and manufactured in Nelson by Gavin Robertson of Potius (www.potius.co.nz). This product has been selected for use in the 3-storey Nelson Marlborough Institute of Technology (NMIT). This is the first Timber Demonstration Building partly funded through a New Zealand Government initiative to promote the use of timber as the superstructure. The timber floor units are prefabricated into double “T” or double “I” units, with concrete topping added on site. On this project the Potius floor will carry the dead load of concrete topping non-compositely, made possible due to the shorter spans provided in this building. This product has also been used in other projects without any concrete topping, and can be designed for timber-concrete composite floor construction.

Recent fire testing at Building Research Association of New Zealand (BRANZ) of timber-concrete composite floors were conducted, and have been detailed in Thesis by O’Neill (2009) at the University of Canterbury. These timber-concrete composite floor provide structural fire resistance, however the New Zealand Building Code (BIA, 2005) prescriptive code requirements for surface finishes do not allow for exposed timber as a feature ceiling, even when sprinklers are provided, so the rationale of this needs to be explored.

1.3 Objectives

The objectives of this research are:

1. To describe a range of timber floor solutions available, including sawn timber joists, glulam and laminated veneer lumber joists, engineered timber "I" joists, parallel timber trusses, timber stressed-skin timber panels, solid timber deck plates such as stress-laminated and cross-laminated, and timber-concrete composite floor systems.
2. To provide a comparison between timber systems and competing systems in other materials, including precast concrete with concrete topping, steel joist with concrete topping, steel-concrete composite, for structural, fire and acoustic performance.
3. To ascertain inherent fire resistance of timber-composite floor systems and to consider use of such systems with fire rated ceilings or without fire rated ceilings where underside is exposed to show a visually aesthetic timber ceiling.
4. To investigate how gypsum plasterboard contributes beneficially to aspects of fire protection and acoustic insulation.

1.4 Scope of Research

1.4.1 Included

The scope of this report is to identify a broad range of timber and timber-concrete composite floor systems. The floor systems are assessed for structural span capability, fire resistance and acoustic performance. The floor systems included are primarily from New Zealand and Australia, plus there is a small selection of systems from further afield. Other aspects indentified include thermal mass and constructability along with recommendations for further research and testing to progress the field of timber and timber-composite floor systems.

1.4.2 Excluded

The origins of timber-concrete composite floors were as retrofit solutions to existing timber floors, to increase load carrying performance while utilising the existing timber members. The retrofitting of floors is not particularly applicable in New Zealand as seismic conditions are not conducive to increasing the floor weight, and is therefore not included in this report. Specialist finite element computer modelling for thermal and structural analysis has not been incorporated, as these would typically require validation with physical laboratory tests.

For the acoustic portion of this report, sound and impact properties will be considered directly through the floor only, as flanking sound through non-direct paths is beyond the scope of this report. This flanking sound leakage through other paths typically occurs through wall to floor joints and specific detailing is required to minimise this mode of sound transport. Flanking tests conducted at Building Research Association of New Zealand (BRANZ) have been reported by Emms and Walther (2008). The results of these have been compiled in report by Emms (2008) and the final BRANZ study report SR0925 is due for completion in the near future. Additional information can be found in report by Nightingale et al (2006) of similar testing conducted at National Research Council in Canada.

1.5 Research Initiatives

1.5.1 Promoting Sustainable Wood-Based Building Materials

The following information was sourced from the Ministry of Agriculture and Forestry (MAF) webpage (www.maf.govt.nz/climatechange/slm/investment-sheets/wood-based-building.htm):

This New Zealand Government programme includes four initiatives:

1. Two Professorship positions established to teach and research the use of timber in building design. Professor Andy Buchanan was appointed as the Professor of Wood Design at the University of Canterbury in 2006, and Professor Pierre Quenneville was appointed to the Chair of Timber Design at the University of Auckland in 2007.
2. NZ Wood website (www.nzwood.co.nz) has been launched to provide Engineers, Architects and Designers with technical information on building in wood.
3. Partial funding of up to two government demonstration buildings to be built in wood that would ordinarily be build in more greenhouse gas intensive materials such as concrete and steel.
4. A new policy requiring all government-funded building projects to include a build-in-wood option for buildings up to four floors including the ground floor.

1.5.2 Build-in-Wood Option

The following information was sourced from NZ Wood webpage (www.nzwood.co.nz/corporate/news/government_initiatives_for_building_in_wood):

Build-in-wood option is a New Zealand Government initiative to encourage use of wood for building the superstructure of buildings, this being the main structural members. The proposal of the previous Labour led government was: "From the third quarter of 2008 all government-funded project proposals for new buildings up to four storeys high will require a build-in-wood option at the initial concept / request-for-proposals stage, with indicative sketches and price estimates". This proposal is now under review from the newly appointed National led government.

The Ministry of Agriculture and Forestry (MAF) has provided partial funding for up to two government buildings with superstructure constructed of wood that would typically be built from other materials. MAF will provide up to $1.25 million per building and these "Demonstration Buildings" are intended for use as education models to further timber design and construction techniques. The first approved Build-in-wood Demonstration Building is the Nelson Marlborough Institute of Technology (NMIT) Arts & Media Centre.

1.5.3 The Structural Timber Innovation Company (STIC)

Direct extracts of information in sections 1.5.3, 1.5.4 and 1.5.5 are shown in **italics**.

The following information was obtained from the University of Canterbury webpage (www.canterbury.ac.nz/ucengage/backissues/may08/new.shtml):

A $10 million research programme has been approved by the Foundation for Research Science and Technology, based on pioneering timber engineering research at the University of Canterbury. The new funding will establish the Structural Timber Innovation Company Ltd (STIC), co-funded by government and industry, with initial funding for five years. The company will develop large-span timber buildings for a wide range of uses in New Zealand, Australia and other export markets.

Andy Buchanan, Professor of Timber Design at Canterbury University (and STIC Research Director), says primary applications will include commercial, industrial and residential buildings. Flexible design will allow for occupancies to change several times during the life of the buildings. He says compared with traditional buildings, these new buildings will be more attractive and more desirable places to live and work, also being of lower weight with easier transport of components and less expensive foundations.

Professor Buchanan says that the sustainability benefits of timber buildings will include lower CO2 emissions due to the low embodied energy of timber materials, lower life-time heating and cooling costs, and carbon sequestration in the building components, all of which will help to meet the Government's carbon neutral objectives. This research will create a step change in New Zealand's wood manufacturing and construction industries, greatly reducing the environmental impacts of buildings.

In addition to the work at Canterbury University, the new company will have major research contracts with the University of Auckland, University of Technology (Sydney), universities in Italy and elsewhere, and with BRANZ Ltd in Wellington.

The following information was sourced from STIC website (www.stic.co.nz):

The New Zealand Government is the largest investor in STIC, through the Foundation for Research, Science and Technology, and will provide funding for 5 years, matching the $5 million industry investment. Founding shareholders are: BRANZ, Carter Holt Harvey Woodproducts, Nelson Pine Industries, New Zealand Pine Manufacturers Association, University of Auckland, University of Canterbury and Wesbeam. Forest and Wood Products Australia is also a major contributor to STIC.

Composite floors

Team leader is Keith Crews, University of Technology, Sydney (UTS)

Fire safety

Team leader is Andy Buchanan, University of Canterbury (UC)

Multi-storey timber buildings 2 to 20+ storeys

Team leader is Andy Buchanan, UC

Roofs and Fasteners

Team leader is Pierre Quenneville, University of Auckland (UA)

Seismic design

Team leader is Stefano Pampanin, UC

Sustainability

Team leader is Stephen John, UC

1.5.4 European Cooperation in Science and Technology (COST)

The European Cooperation in Science and Technology (COST) is a flexible, fast, effective and efficient tool to network and coordinate nationally funded research activities, bringing scientists together under light strategic guidance and letting them work out their ideas. COST is based on networks, called COST Actions, centred around research projects in fields that are of interest to at least five COST countries (www.cost.esf.org).

In total, there are 36 COST countries, 35 member states, plus one cooperating state: Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Israel (cooperating state), Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

Forests, their Products and Services (FPS) Domain:

E24:	*Reliability of Timber Structures*
E29:	*Innovative Timber and Timber-Composite Elements for Buildings*
E55:	*Modelling of the Performance of Timber Structures*
FP0702:	*Net- Acoustics for Timber Based Lightweight Buildings and Elements*

Transport and Urban Development (TUD) Domain:

C26:	*Urban Habitat Constructions under Catastrophic Events*
TU0901:	*Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions*
TU0904:	*Integrated Fire Engineering and Response*

The relevant research issues for COST E29 are grouped into the following Working Groups:

WG1:	*Design, construction and manufacturing*
WG2:	*Fire Safety*
WG3:	*Acoustics, low frequency vibration and thermal performance*
WG4:	*Environmental impacts and durability*
WG5:	*Documentation*
WG6:	*Earthquake engineering and connections*
WG7:	*Conformity assessment*

1.5.5 CIB Working Commission W18

From webpage (www.cibworld.nl/site/home/index.html): *CIB is the acronym of the abbreviated French (former) name: "Conseil International du Bâtiment" (in English this is: International Council for Building). In the course of 1998, the abbreviation has been kept but the full name changed into: International Council for Research and Innovation in Building and Construction.*

CIB was established in 1953 as an Association whose objectives were to stimulate and facilitate international cooperation and information exchange between governmental research institutes in the building and construction sector, with an emphasis on those institutes engaged in technical fields of research. CIB has since developed into a worldwide network of over 5000 experts from about 500 member organisations with a research, university, industry or government background, who collectively are active in all aspects of research and innovation for building and construction.

From webpage (www.rz.uni-karlsruhe.de/~gc20/IHB/cib.htm): *CIB Working Commission W18 "Timber Structures" intends to serve as an interface between code and standards writing bodies (such as CEN and ISO), design engineers and research engineers in the development of methods for the design of safe and economic timber structures, based on rational analysis and well-defined material properties that can readily be obtained by testing*

The Commission organizes annual meetings (since 1973), at which papers are being presented and discussed on the following topics:

- *Timber columns*
- *Stress grading*
- *Stresses for solid timber*
- *Timber joints and fasteners*
- *Duration of load*
- *Environmental condition*
- *Laminated members*
- *Trussed rafters*
- *Structural stability*
- *Structural design codes*

1.6 Outline of Research Report

Chapter 1 **Introduction**

This chapter describes the background of this research and defines the scope and objectives. Current timber research initiatives are also presented.

Chapter 2 **Performance Requirements for Floor Systems**

This chapter extracts relevant sections of New Zealand Building Code requirements and Building Code of Australia requirements.

Chapter 3 **Outline Procedures for Floor Systems**

This chapter outlines typical procedures to design floor systems. The sections are structural, fire, acoustic and energy efficiency.

Chapter 4 **Assessment of Timber Floor Systems**

This chapter provides information and methods for the assessment of timber floor systems. The sections are structural, fire, acoustic and energy efficiency.

Chapter 5 **Types of Floor Systems**

This chapter includes a range of timber and timber-composite floor systems typically used or under development in New Zealand and around the world.

Chapter 6 **Structural Performance of Timber Floor Systems**

This chapter details information on structural performance for the various timber floor systems identified.

Chapter 7 **Fire Performance of Timber Floor Systems**

This chapter details information on fire performance for the various timber floor systems identified.

Chapter 8 **Acoustic Performance of Timber Floor Systems**

This chapter details information on acoustic performance for the various timber floor systems identified.

Chapter 9 **Summary of Floor System Performance**

This chapter summarises the structural, fire and acoustic performance aspects from the preceding chapters.

Chapter 10 **Ceilings, Floor Underlays, Floor Coverings**

This chapter outlines typical ceiling systems to protect the underside of floors and includes a floor underlay system that offers fire and acoustic performance.

Chapter 11 **Timber Floor Systems in Buildings**

This chapter includes a selection of timber buildings built in New Zealand and around the world, and examines the incorporated timber floor systems.

Chapter 12 **Conclusions**

Chapter 13 **References**

Appendices

2. Performance Requirements for Floor Systems

This chapter extracts relevant sections of New Zealand Building Code requirements and Building Code of Australia requirements.

2.1 New Zealand Building Code Requirements

The New Zealand Building Code (DBH, 2005) provides various requirements to achieve building compliance. Direct extracts from this document are shown in **italics**.

2.1.1 Building Control Framework

The New Zealand Building Code has several performance requirements for buildings. Acceptable solutions within this code provide a prescriptive approach to achieving a minimum level of performance. Alternatively, performance requirements can be achieved by specific design and detailing to demonstrate compliance with the building code. Floor systems within a building need to satisfy several aspects including fire resistance, acoustic performance and structural capacity. Other factors that are important for selecting floor systems include cost, constructability and environmental impact.

From the New Zealand Building Code Handbook (DBH, 2007):

The regulation and performance of buildings site under the following three-part framework:

1. *The **Building Act**, which contains the provisions for regulating building work.*
2. *The **Building Regulations** contain prescribed forms and list specified systems.*
3. *The **Building Code**, contained in Schedule 1 of the Building Regulations 1992, which sets out performance standards all new building work must meet, and covers aspects such as stability, fire safety, access, moisture, safety of users, services and facilities, and energy efficiency.*

These parts forming the top three tiers of the pyramid (see Figure 2.1), show mandatory building legislation that must be followed. The rest of the diagram shows various paths that may be used to demonstrate compliance with the Building Code. With the exception of alternative solutions, the paths illustrated in Figure 2.1 must be accepted by the building consent authority as meeting the performance requirements of the Building Code.

Compliance Documents

These paths that are deemed to meet the performance requirements of the Building Code that they cover (see Figure 2.1):

- *Verification Methods*
- *Acceptable Solutions*
- *NZS4121:2001 Design for Access and Mobility: Buildings and Associate Facilities*
- *Determination*
- *Product Certification*
- *Energy Work Certificate*

Alternative Solutions

Proposed work in this category must demonstrate compliance with the performance requirements of the Building Code to the satisfaction of a building consent authority (see Figure 2.1):

- *Comparison to the Compliance Document*
- *Comparison to Documents: Standard, Technical Information, and Tests/Research*
- *In-Service History*

The following figure was obtained from NZCB Handbook (DBH, 2007):

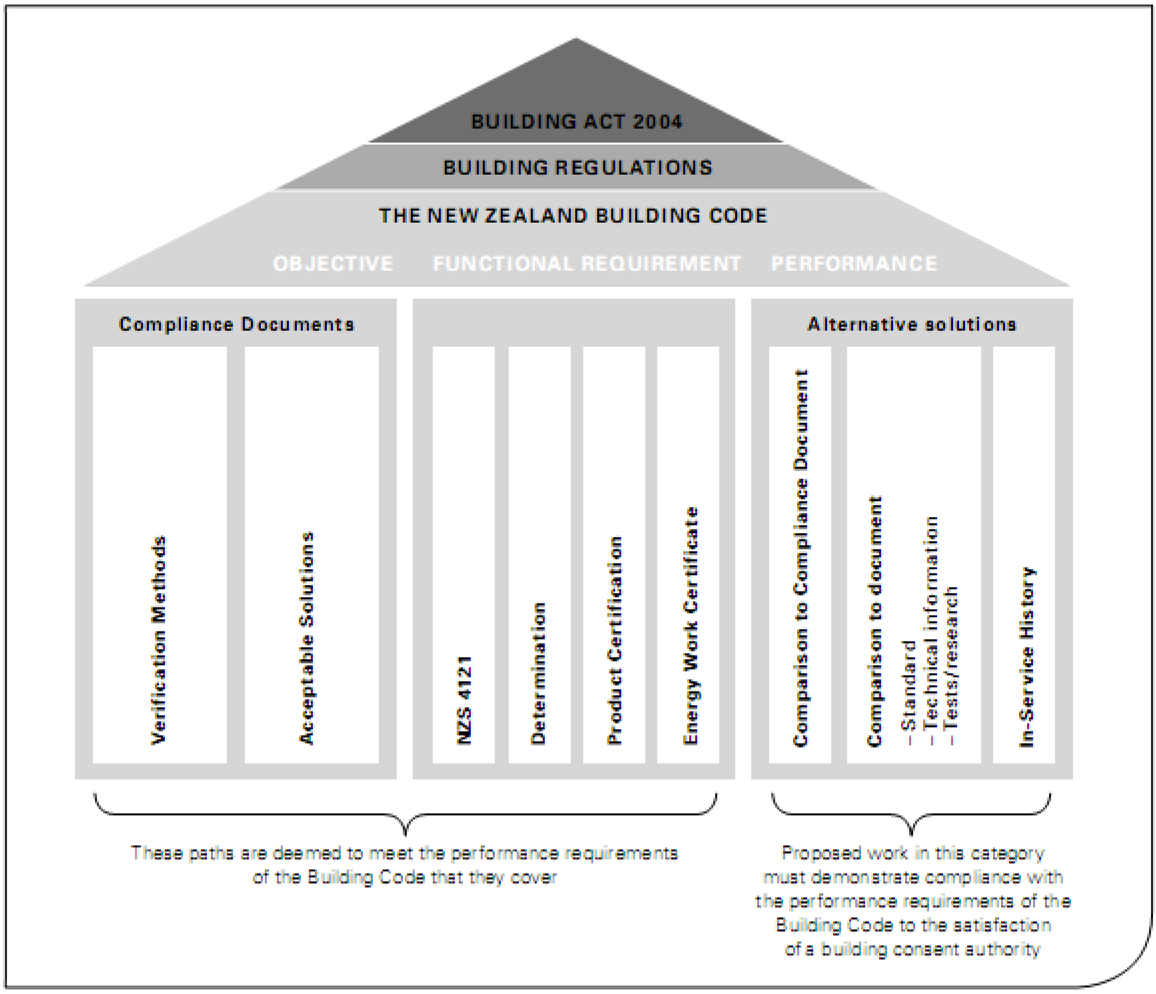


Figure 2.1 – Hierarchy of New Zealand Building Controls

The Building Code consists or 2 preliminary clauses and 35 technical clauses. Each technical clause has three levels that describe the requirements for the clause, as follows:

1. Objective.

Social objectives the building must achieve.

2. Functional Requirement.

Functions the building must perform to meet the Objective.

3. Performance.

The performance criteria the building must achieve. By meeting the performance criteria, the Objective and Functional requirement can be achieved.

2.1.2 Structural Requirements

The New Zealand Building Regulations (BIA, 1992) describe the objective, functional requirement and performance for:

Clause B1 – Structure
Clause B2 – Durability

B1 and B2 are both relevant clauses for floor systems.

Clause B1 – Structure

B1.1 ***Objective*** *– The objective of this provision is to:*

(a) safeguard people from injury caused by structural failure,
(b) safeguard people from loss of amenity caused by structural behaviour, and
(c) protect other property from physical damage caused by structural failure.

B1.2 ***Functional Requirement*** *– Buildings, building elements and sitework shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives.*

B1.3.1 ***Performance*** *– Buildings, building elements and sitework shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives.*

B1.3.2 ***Performance*** *– Buildings, building elements and sitework shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use.*

B1.3.3 ***Performance*** *– Account shall be taken of all physical conditions likely to affect the stability of buildings, building elements and sitework, including:*

(a) self-weight,
(b) imposed gravity loads arising from use,
(c) temperature,
(d) earth pressure,

(e) *water and other liquids,*

(f) *earthquake,*

(g) *snow,*

(h) *wind,*

(i) *fire,*

(j) *impact,*

(k) *explosion,*

(l) *reversing or fluctuating effects,*

(m) *differential movement,*

(n) *vegetation,*

(o) *adverse effects due to insufficient separation from other buildings,*

(p) *influence of equipment, services, non-structural elements and contents,*

(q) *time dependent effects including creep and shrinkage, and*

(r) *removal of support.*

The factors most relevant for floor systems are: self-weight, imposed gravity loads arising from use, temperature, earthquake, wind, fire, impact, reversing or fluctuating effects, differential movement, influence of equipment, services, non-structural elements and contents, time dependent effects including creep and shrinkage, and removal of support.

Clause B2 – Durability

B2.1 ***Objective*** *– The objective of this provision is to ensure that a building will throughout its life continue to satisfy the other objectives of this code.*

B2.2 ***Functional Requirement*** *– Building materials, components and construction methods shall be sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of this code throughout the life of the building.*

B2.3.1 ***Performance*** *– Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building, if stated or the life of the building, being not less than 50 years, if those building elements (including floors, walls, and fixings) provide structural stability to the building.*

2.1.3 Fire Requirements

The New Zealand Building Regulations (BIA, 1992) describe the objective, functional requirement and performance within the four fire safety clauses:

Clause C1 – Outbreak of Fire
Clause C2 – Means of Escape
Clause C3 – Spread of Fire
Clause C4 – Structural Stability during Fire

C3 and C4 are the relevant clauses for floor systems.

Clause C3 – Spread of Fire

C3.1 ***Objective*** *– The objective of this provision is to: safeguard people from injury or illness when evacuating a building during fire; provide protection to fire service personnel during firefighting operations; protect adjacent household units, other residential units, and other property from the effects of fire; safeguard the environment from adverse effects of fire.*

C3.2 ***Functional Requirement*** *– Buildings shall be provided with safeguards against fire spread so that: occupants have time to escape to a safe place without being overcome by the effects of fire; firefighters may undertake rescue operations and protect property; adjacent household units, other residential units, and other property are protected from damage; and significant quantities of hazardous substances are not released to the environment during fire.*

C3.3.1 ***Performance*** *– Interior surface finishes on walls, floors, ceilings and suspended building elements, shall resist the spread of fire and limit the generation of toxic gases, smoke and heat, to a degree appropriate to: the travel distance; the number of occupants; the fire hazard; and the active fire safety systems installed in the building.*

C3.3.2 ***Performance*** *– Fire separations shall be provided within buildings to avoid the spread of fire and smoke to: other firecells; spaces intended for sleeping; and household units within the same building or adjacent buildings; other property.*

C3.3.4 ***Performance*** *– Concealed spaces and cavities within buildings shall be sealed and subdivided where necessary to inhibit the unseen spread of fire and smoke.*

C3.3.9 ***Performance*** *– The fire safety systems installed shall facilitate the specific needs of fire service personnel to: carry out rescue operations; and control the spread of fire.*

Clause C4 – Structural Stability during Fire

C4.1 ***Objective*** *– The objective of this provision is to: safeguard people from injury due to loss of structural stability during fire, and protect household units; and other property from damage due to structural instability caused by fire.*

C4.2 ***Functional Requirement*** *– Buildings shall be constructed to maintain structural stability during fire to: allow people adequate time to evacuate safely; allow fire service personnel adequate time to undertake rescue and firefighting operations; and avoid collapse and consequential damage to adjacent household units or other property.*

C4.3.1 ***Performance*** *– Structural elements of buildings shall have fire resistance appropriate to the function of the elements, the fire load, the fire intensity, the fire hazard, the height of the buildings and the fire control facilities external to and within them.*

C4.3.2 ***Performance*** *– Structural elements shall have a fire resistance of no less than that of any element to which they provide support within the same firecell.*

C4.3.3 ***Performance*** *– Collapse of elements having lesser fire resistance shall not cause the consequential collapse of elements required to have a higher fire resistance.*

2.1.4 Acoustic Requirements

The New Zealand Building Regulations (BIA, 1992) describe the objective, functional requirement and performance for:

Clause G6 – Airborne and Impact sound

G6.1 ***Objective*** *– The objective of this provision is to safeguard people from illness or loss of amenity as a result of undue noise being transmitted between abutting occupancies.*

G6.2 ***Functional Requirement*** *– Building elements which are common between occupancies, shall be constructed to prevent undue noise transmission from other occupancies or common spaces, to the habitable spaces of household units.*

G6.3.1 ***Performance*** *– The Sound Transmission Class of walls, floors and ceilings, shall be no less than 55.*

G6.3.2 ***Performance*** *– The Impact Insulation Class of floors shall be no less than 55.*

2.1.5 Energy Efficiency Requirements

The New Zealand Building Regulations (BIA, 1992) describe the objective, functional requirement and performance for:

Clause H1 – Energy Efficiency

H1.1 ***Objective*** *– The objective of this provision is to facilitate efficient use of energy.*

H1.2 ***Functional Requirement*** *– Buildings must be constructed to achieve an adequate degree of energy efficiency when that energy is used for: modifying temperature or humidity, or both; or providing hot water to sanitary fixtures or sanitary appliances, or both; or providing artificial lighting.*

H1.3.3 ***Performance*** *– The building envelope enclosing spaces where the temperature or humidity (or both) are modified must be constructed to: provide adequate thermal resistance; and limit uncontrollable airflow. Account must be taken of physical conditions likely to affect energy performance of buildings, including: the* ***thermal mass*** *of building elements; the building orientation and shape; the air-tightness of the building envelope; the heat gains from services, processes and occupants; the local climate; heat gains from solar radiation.*

2.2 Australian Building Code Requirements

The Building Code of Australia (ABCB, 2007a) provides various requirements to achieve building compliance. Direct extracts from this document are shown in **italics**.

2.2.1 BCA Structure

The Building Code of Australia has several performance requirements for buildings. Acceptable solutions within this code provide a prescriptive approach to achieving a minimum level of performance. Alternatively, performance requirements can be achieved by specific design and detailing to demonstrate compliance with the building code. Floor systems within a building need to satisfy several aspects including structural capacity, fire resistance, acoustic performance and thermal mass potential. Other factors that are important for selecting floor systems include cost, constructability and environmental impact.

The structure of the BCA comprised the following as shown in following figure (ABCB, 2007a):

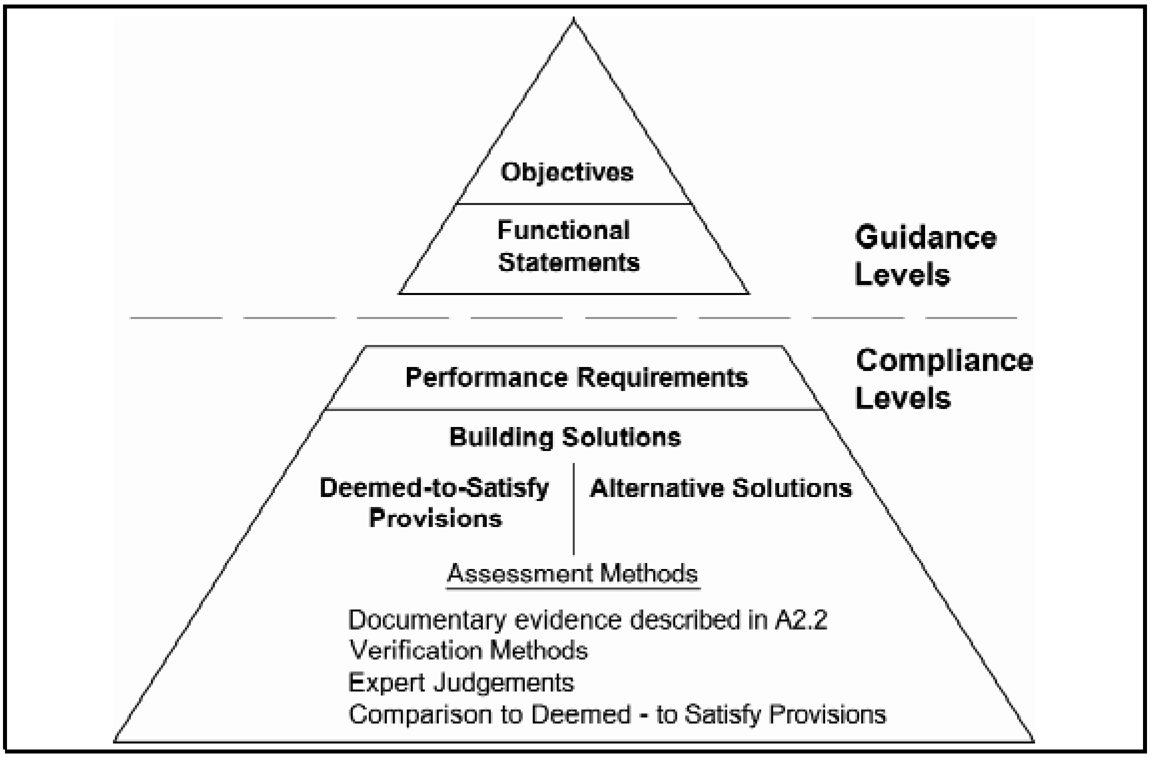


Figure 2.2 – BCA Structure

Compliance with the BCA

A Building Solution will comply with the BCA if it satisfies the Performance Requirements.

Meeting the Performance Requirements

Compliance with the Performance Requirements can only be achieved by:

(a) complying with the Deemed-to-Satisfy Provisions, or

(b) formulating an Alternative Solution which:

(i) complies with the Performance Requirements, or

(ii) is shown to be at least equivalent to the Deemed-to-Satisfy Provisions, or

(c) a combination of (a) and (b).

Objectives and Functional Statements

The Objectives and Functional Statements may be used as an aid to interpretation.

Deemed-to-Satisfy Provisions

A Building Solution which complies with the Deemed-to-Satisfy Provisions is deemed to comply with Performance Requirements.

Alternative Solutions

(a) An Alternative Solution must be assessed according to one or more of the Assessment Methods.

(b) An Alternative Solution will only comply with the BCA if the Assessment Methods used to determine compliance with the Performance Requirements have been satisfied.

(c) The Performance Requirements relevant to an Alternative Solution must be determined in accordance with A0.10 (Relevant Performance Requirements below).

Assessment Method

The following Assessment Method, or combination of them, can be used to determine that a Building Solution complies with the Performance Requirements:

(a) Evidence to support that the use of a material, form of construction of design meets a Performance Requirement of a Deemed-to-Satisfy Provision as described in A2.2 (Evidence of Suitability in BCA, 2007).

(b) Verification Methods such as:

- *(i) the Verification Methods in the BCA, or*
- *(ii) such other Verification Methods as the appropriate authority accepts for determining compliance with the Performance Requirements.*

(c) Comparison with the Deemed-to-Satisfy Provisions.

(d) Expert Judgement.

Relevant Performance Requirements (A0.10)

In order to comply with the provisions of A1.5 (to comply with Sections A to J inclusive) the following method must be used to determine the Performance Requirement or Performance Requirements relevant to the Alternative Solution:

(a) Identify the relevant Deemed-to-Satisfy Provision of each Section or Part that is to be the subject of the Alternative Solution.

(b) Identify the relevant Performance Requirements from the same Sections or Parts that are relevant to the identified Deemed-to-Satisfy Provisions.

(c) Identify Performance Requirements from other Sections and Parts that are relevant to any aspects of the Alternative Solution proposed or that are affected by the application of the Deemed-to-Satisfy Provision, that are the subject of the Alternative Solution.

2.2.2 Structural Requirements

The Building Code of Australia (BCA) describes the objective, functional statement and performance requirement for:

Part B1 – Structural Provisions

B01 ***Objective*** *– The objective of this Part is to:*

(a) safeguard people from injury caused by structural failure,
(b) safeguard people from loss of amenity caused by structural behaviour, and
(c) protect other property from physical damage caused by structural failure.

BF1.1 ***Functional Statement*** *– A building or structure is to withstand the combination of loads and other actions to which it may be reasonably subjected.*

BP1.1 ***Performance Requirement –***

(a) A building or structure, to the degree necessary, must:

(i) remain stable and not collapse; and
(ii) prevent progressive collapse; and
(iii) minimise local damage and loss of amenity through excessive deformation, vibration or degradation; and
(iv) avoid causing damage to other properties,

by resisting the actions to which it may reasonable be subjected.

(b) The actions to be considered to satisfy (a) include but are not limited to:

(i) permanent actions (dead loads),
(ii) imposed actions (live loads arising from occupancy and use),
(iii) wind action,
(iv) earthquake action,
(v) snow action,
(vi) liquid pressure action,
(vii) ground water action,
(viii) rainwater action (including ponding action),

(ix) *earth pressure action,*

(x) *differential movement,*

(xi) *time dependent effects (including creep and shrinkage),*

(xii) *thermal affects,*

(xiii) *ground movement, and*

(xiv) *construction activity*

The factors most relevant for floor systems are: permanent actions (dead loads), imposed actions (live loads arising from occupancy and use), wind action, earthquake action, differential movement, time dependent effects (including creep and shrinkage), thermal affects and construction activity.

BP1.2 ***Performance Requirement*** *– The structural resistance of materials and forms of construction must be determined using five percentile characteristic material properties with appropriate allowance for:*

(a) *known construction activities,*

(b) *type of material,*

(c) *characteristics of the site,*

(d) *the degree of accuracy inherent in the methods used to assess the structural behaviour,*

(e) *action effects arising from the differential settlement of foundations, and from restrained dimensional changes due to temperature, moisture, shrinkage, creep and similar effects.*

2.2.3 Fire Requirements

The Building Code of Australia (BCA) describes the objective, functional statement and performance requirement for:

Section C – Fire Resistance

C01 ***Objective*** *– The objective of this Section is to:*

(a) safeguard people from illness of injury due to a fire in a building,
(b) safeguard occupants from illness or injury when evacuating a building during a fire,
(c) facilitate the activities of emergency services personnel,
(d) avoid the spread of fire between buildings, and
(e) protect other property from physical damage caused by structural failure of a building as a result of fire.

CF1 ***Functional Statement*** *– A building or structure is to be constructed to maintain structural stability during fire to:*

(a) allow occupants time to evacuate safely,
(b) allow for fire brigade intervention, and
(c) avoid damage to other property.

CF2 ***Functional Statement*** *– A building is to be provided with safeguards to prevent fire spread:*

(a) so that occupants have time to evacuate safely without being overcome by the effects of fire, and
(b) to allow for fire brigade intervention, and
(c) to sole-occupancy units providing sleeping accommodation, and
(d) to adjoining fire compartments, and
(e) between buildings.

CP1 ***Performance Requirement*** *– A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to:*

(a) the function or use of the building,
(b) the fire load,
(c) the potential fire intensity,
(d) the fire hazard,
(e) the height of the building,
(f) its proximity to other property,
(g) any active fire safety systems installed in the building,
(h) the size of any fire compartmentation,
(i) fire brigade intervention,
(j) other elements they support, and
(k) evacuation time.

CP2 ***Performance Requirement*** *– A building must have elements which will, to the degree necessary, avoid the spread of fire:*

(a) to exits,
(b) to sole-occupancy units and public corridors,
(c) between buildings, and
(d) in a building.

CP4 ***Performance Requirement*** *– A material and an assembly must, to the degree necessary, resist the spread of fire to limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to:*

(a) the evacuation time,
(b) the number, mobility and other characteristics of occupants,
(c) the function or use of the building, and
(d) any active fire safety systems installed in the building.

CP7 ***Performance Requirement*** *– A building must have elements which will, to the degree necessary, avoid the spread of fire so that emergency equipment provided in a building will continue to operate for a period of time necessary to ensure that the intended function of the equipment is maintained during a fire.*

CP8 ***Performance Requirement*** *– A building element provided to resist the spread of fire must be protected, to the degree necessary, so that and adequate level of performance is maintained:*

(a) *where openings, construction joints and the like occur, and*

(b) *where penetrations occur for building services.*

2.2.4 Acoustic Requirements

The Building Code of Australia (BCA) describes the objective, functional statement and performance requirement for:

Part F5 – Sound Transmission and Insulation

F05 ***Objective*** *– The objective of this Part is to safeguard people from illness or loss of amenity as a result of undue sound being transmitted:*

(a) between adjoining sole-occupancy units,
(b) from common spaces to sole-occupancy units,
(c) from parts of different classifications to sole-occupancy units,

FF5.1 ***Functional Statement*** *– A part of building that separates sole-occupancy units, or separates a sole-occupancy unit from a common space or part of another classification within the building is to be constructed to prevent undue sound transmission.*

FP5.1 ***Performance Requirement*** *– Floors separating:*

(a) sole-occupancy units, or
(b) a sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, public lobby, or the like, or a part of a different classification,

must provide insulation against the transmission of airborne and impact generated sound sufficient to prevent illness of loss of amenity to the occupants.

FP5.3 ***Performance Requirement –*** *The required sound insulation of a floor or a wall must not be compromised by:*

(a) the incorporation or penetration of a pipe or other service element or
(b) a door assembly.

2.2.5 Energy Efficiency Requirements

The Building Code of Australia (BCA) describes the objective, functional statement and performance requirement for:

Section J – Energy Efficiency

J01 ***Objective*** *– The objective of this Section is to reduce greenhouse gas emissions by efficiently using energy.*

JF1 ***Functional Statement*** *– A building, including its services, must have, to the degree necessary, features that facilitate the efficient use of energy appropriate to:*

(a) the function and use of the building and services,
(b) the internal environment,
(c) the geographical location of the building,
(d) the effects of nearby permanent features such as topography, structures and buildings,
(e) solar radiation being:

(i) utilised for heating,
(ii) controlled to minimise energy for cooling,

(f) the sealing of the building envelope against air leakage,
(g) the utilisation of air movement to assist heating and cooling, and
(h) the energy source of the services.

JF2 ***Functional Statement*** *– A building, including its services, must have, to the degree necessary, features that facilitate the maintenance of systems and components appropriate to the function and use of the building.*

3. Outline Procedures for Floor Systems

This chapter outlines typical procedures to design floor systems. The sections are structural, fire, acoustic and energy efficiency.

3.1 Structural Procedure

Outline typical procedures for floor structural design. These are similar for New Zealand and Australia, with use of shared loadings code, identical except for seismic requirements.

1. Client specified requirements: brief, budget, time schedule
2. Building use/occupancy
3. Structural type
4. Form of construction
5. Material selection
6. Dead load
7. Live load
8. Combined actions
9. Floor span
10. Strength capacity
11. Deflection
12. Floor vibration
13. Floor diaphragm performance

Client's Project Brief

Determine the Client's specific building requirements with regards to project briefing, estimated build budget, time schedule and any constraints.

Building Use/Occupancy

Determine the building use and projected occupancy within various building spaces.

Structural Type

Provide concept of structural type, such as shear walls or moment resisting frames.

Form of Construction

Consider off-site prefabricated building elements and on-site building requirements.

Material Selection

Select material based on capability, durability, economics and sustainability.

Dead Load

Determine dead load of selected material systems.

Live Load

Determine applicable live load for intended occupancy and consider also possible alternative building use for future flexibility of building space.

Combined Actions

Combination of factored loads: dead, live, wind, seismic and others.

Floor Span

Identify various floor spans.

Strength Capacity

Calculate structural moment resistance of floor section.

Deflection

Calculate short and long term floor deflections.

Floor Vibration

Assess floor vibration characteristics.

Floor Diaphragm Performance

Assess floor diaphragm rigidity/flexibility.

3.2 Fire Procedure

3.2.1 NZBC – Fire Procedure

Outline typical procedure for floor fire design in accordance with NZBC:

1. Purpose Group
2. Fire Hazard Category
3. Occupant Load
4. Means of Escape
5. Firecells
6. Fire Safety Precautions
7. Fire Resistance
8. Control of Internal Fire and Smoke Spread
9. Control of External Fire Spread
10. Fire Fighting

3.2.1.1 Purpose Group

The purpose group or groups are classification of various spaces within a building according to the activity for which the spaces are used. The purpose group is used as an entry point to several parts of the acceptable solution, e.g. when determining the number and size of exitways and other fire safety precautions (DHB, 2005).

Typical buildings include: education, commercial, hotel accommodation, residential apartments and hospitals. These building types have associated purpose groups and fire hazard category. Purpose groups are separated into activities: crowd activities, sleeping activities, working/business/storage activities and intermittent activities.

Table 3.1 – Purpose Groups (NZBC)

Purpose Group	Crowd Activities	Fire hazard category
CS	Crowd Small	1
CL	Crowd Large	2 or 3
CO	Crowd Open	1
CM	Crowd Merchandise	2 or 4
Purpose Group	**Sleeping Activities**	**Fire hazard category**
SC	Sleeping Care	1
SD	Sleeping Detention	1
SA	Sleeping Accommodation	1
SR	Sleeping Residential	1
SH	Sleeping Household	1
Purpose Group	**Work Activities**	**Fire hazard category**
WL	Working Low	1 or 2
WM	Working Medium	3
WH	Working High	4
WF	Working Fast	4
Purpose Group	**Intermittent Activities**	**Fire hazard category**
IE	Intermittent Escape	1
IA	Intermittent Low	1
ID	Intermittent Medium	3

3.2.1.2 Fire Hazard Category (FHC)

The fire hazard category is used to classify purpose groups or activities having a similar fire hazard into four categories, numbered 1 to 4 in order of increasing fire severity. Each number has a corresponding range of fire load energy density (FLED) with design value of FLED taken from the upper portion of each range with the exception of fire hazard category 4 which does not give an upper limit. The structural fire endurance rating (S) requirements within Part 4 of the NZBC are a function of the selected fire hazard category.

From DHB (2005): While there is a relationship between the fire hazard category and the Fire Load Energy Density (FLED), it is recognised that FLED is only one factor affecting the fire severity and thus the impact of the fire on the building structure. Other important factors may include ventilation, surface area to mass ratio of the fuel, and its rate of burning. The fire hazard category was chosen in preference to FLED because it is better able to categorise certain spaces containing mainly low heat release rate fuels. While FHC covers more than just the energy density of the fire load, there is a direct link between these two parameters, as tabulated below:

Table 3.2 – Fire Hazard Categories (NZBC)

Fire Hazard Category	Range of FLED (MJ/m²)	Design Value of FLED (MJ/m²)
1	0 to 500	400
2	501 to 1000	800
3	1001 to 1500	1200
4	> 1500	Not given

3.2.1.3 Occupant Load

The occupant load is identified by the purpose group and the maximum number of occupants forming that group within the various spaces that can be occupied throughout a building. The occupant density varies considerably by what activity is conducted in a particular space. The number of occupants is assessed for each floor of a building and for various areas across each floor when there are multiple activities or purposes. The size and location of escape routes and the fire safety precautions applied to them in a building are related to the occupant load (DBH, 2005).

3.2.1.4 Means of Escape

Not applicable for floor systems.

3.2.1.5 Firecells

Floors elements in buildings with two or more storeys offer a typically continuous horizontal division that presents a logical opportunity to provide fire separation in the vertical direction. The main openings within a floor are the stairs and lifts which are typically separated from the rest of the floor with surrounding walls to form a protective core to allow escape of occupants. These stair and lift core walls typically contribute significantly to the lateral load resisting structure of the building.

A building may comprise one or more firecells depending on the fire hazard. Firecells are required to contain a fire for sufficient time to allow safe evacuation and to prevent fire spreading to other firecells or adjacent buildings. Fire cells may also be divided into smoke cells to prevent the spread of smoke and hot gases during escape (DHB, 2005). Firecell floor area limits assist fire-fighting operations, and are set to limit total fire load to approximately 2,000,000 MJ in unsprinklered firecells. Where a firecell is sprinklered, the firecell floor area may be unlimited except when purpose groups require subdivision or other area limitations are imposed by the NZBC compliance document. The floor area to which an S rating applies, shall not exceed the maximum firecell floor area given in the following table (DHB, 2005).

Table 3.3 – Firecell Floor Area Limits (NZBC)

Fire Hazard Category	Maximum Firecell Floor Area (m^2)
1	5000
2	2500
3	1500
4	**SD**

SD = requires Specific Fire Engineering Design

3.2.1.6 Fire Safety Precautions

Fire safety precautions (FSPs) are the combination of all methods used in a building to warn people of an emergency, provide for evacuation, and restrict the spread of fire. This includes both active and passive fire protection (DHB, 2005).

Table 3.4 – Fire Safety Precautions (NZBC)

Type	Description
1	Domestic smoke alarm system.
2	Manual fire alarm system.
3	Automatic fire alarm system with heat detectors and manual call points.
4	Automatic fire alarm system with smoke detectors and manual call points.
5	Automatic fire alarm system with modified smoke/heat detectors and MC points.
6	Automatic fire sprinkler system with manual call points.
7	Automatic fire sprinkler system with smoke detectors and manual call points.
8	Voice communication system.
9	Smoke control in air handling system.
10	Natural smoke venting.
11	Mechanical smoke extract.
12	–
13	Pressurisation of safe paths.
14	Fire hose reels.
15	Fire Service lift control.
16	Visibility in escape routes.
17	Emergency electrical power supply.
18	Fire hydrant system.
19	Refuge areas.
20	Fire systems centre.

3.2.1.7 Fire Resistance

Fire Resistance Rating (FRR)

Fire resistance rating (FRR) is the term used to classify fire resistance of primary and secondary elements as determined in the standard test for fire resistance, or in accordance with a specific calculation method verified by experimental data from standard fire resistance tests. It comprises three numbers giving the time in minutes for which each of the criteria stability, integrity and insulation are satisfied, and is presented always in that order.

The values applied to each of the three components of the FRR, depend on the function and location of the building element to which the FRR applies. In some cases all three numbers will be the same. In others, the numbers will differ and some may have a value of zero (DHB, 2005). For example FRR 60/60/60 indicates each of these criteria require 60 minutes which is applicable for element such as floors and load bearing walls, while FRR -/60/60 may be appropriate for a non-load bearing wall and FRR 60/-/- for a structural beam or column element.

Firecell Rating (F)

Firecell rating (F) is the fire resistance rating intended to prevent fire spread to another firecell, to allow sufficient time to provide for safe evacuation of occupants and protection of adjacent household units and sleeping areas in the building of fire origin and fire fighters engaged in fire fighting and rescue operations (DHB, 2005).

See **Appendix A** of this report for Tables 4.1/1, 4.1/2, 4.1/3, 4.1/4, 4.1/5 extracted from Part 4 of NZBC Acceptable Solution C/AS1 (DHB, 2005). These outline which fire safety precautions are required for the various purpose groups taking into account occupancy numbers and building escape height. Within this series of tables, the F rating is determined by Various factors: purpose group, number of occupants and number of storey levels. Typically, the F rating increases as the number of occupants and number of storey levels increase.

A 50% reduction is applied to the F rating if fire sprinklers are installed where such installation is not a requirement, otherwise the tables already include for this reduction where sprinklers are already required. Clause 6.2.1 of NZBC (DHB, 2005) states: Where adjoining fire cells on the same floor level are permitted by Table 4.1 to have a F rating of F0, they shall be separated from one another. The fire separations shall have a fire resistance rating of no less than that required by Part 6 or Part 7 (for a specific purpose group of situation), or 30/30/30, whichever is the greater.

Structural Fire Endurance Rating (S)

Structural fire endurance rating (S) is the fire resistance rating intended to prevent fire spread or structural collapse for the complete burnout of the firecell. The S rating is aimed at preventing collapse and fire spread which would damage other property, and ensuring that areas of external wall not permitted to be unprotected area contain an internal fire for the S rating time (DHB, 2005).

S rating is a function of the fire hazard category and ventilation during fire. Typically glass windows break from the heat of a fire, allowing fresh air to mix with fuel from building and contents. The S rating decreases with increased ventilation and conversely increases with an increase of fire hazard category. A 50% reduction is applied to the S rating if fire sprinklers are installed within fire hazard categories 1, 2 and 3.

3.2.1.8 Control of Internal Fire and Smoke Spread

Floor elements offer an opportunity to provide smoke separation (smokecells) as well as fire separation (firecells).

Fire and smoke control is achieved by using one or more of the following (DHB, 2005):

(a) Subdividing firecells into smaller firecells or smokecells.

(b) Separating high risk activities from other activities, especially from sleeping purpose groups.

(c) Ensuring the integrity of construction joints and closures in fire separations and smoke separations.

(d) Preventing the movement of fire and smoke though concealed spaces and service ducts.

(e) Using appropriate materials and surface finished.

(f) Installing equipment which, when fire occurs, activates automatically to suppress fire and smoke spread.

Table 3.5 – Ceiling Surface Finishes (NZBC)

Purpose Group	Location	Maximum permitted index		
		SFI	SDI	FI
All purpose groups	Exitways	0	≤ 3	–
SC, SD	Sleeping areas	0	≤ 3	–
CS, CL	Occupied spaces	≤ 2	≤ 5	–
CM	Occupancy > 50	≤ 2	≤ 5	–
SA	Sleeping areas	≤ 2	≤ 5	–
All except SH, SR	Passageways etc. not being part of exitway	≤ 7	≤ 5	–
All except SH, SR	Occupied spaces, minimum requirement	≤ 5 ≤ 9	≤ 10 ≤ 8	–
SH, SR	Within individual units	Nil requirement		

3.2.1.9 Control of External Fire Spread

Not applicable for floor systems.

3.2.1.10 Fire Fighting

Not applicable for floor systems.

3.2.2 BCA – Fire Procedure

Outline typical procedure for floor fire design in accordance with BCA:

1. Classification of Building
2. Type of Construction Required
3. Fire Resistance Level of Building Elements
4. Fire Hazard Properties
5. Material Groups Permitted
6. General Floor Area and Volume Limitations
7. Protection of Openings
8. Provision for Escape
9. Requirements for Sprinklers
10. Fire Fighting Equipment
11. Smoke Hazard Management

3.2.2.1 Classification of Building

The classification of a building or part of a building is determined by the purpose for which it is designed, constructed or adapted to be used (ABCB, 2007a). This is very similar to Purpose Group classification in the NZBC, however fire aspects that follow differ between the two codes, particularly in how fire resistance is determined and the level of fire resistance required appears considerably greater for BCA buildings.

Table 3.6 – Classification of Buildings (BCA)

Classification	Description
Class 1a	Single dwelling
Class 1b	Boarding house, Guest house, Hostel
Class 2	Sole-occupancy units (2 or more adjoining)
Class 3	Residential building (other than Class 1 or 2)
Class 4	Dwelling within Class 5, 6, 7, 8 or 9
Class 5	Office building
Class 6	Retail building
Class 7a	Car park
Class 7b	Storage
Class 8	Laboratory or Production building
Class 9a	Health care building
Class 9b	Assembly building
Class 9c	Aged care building

3.2.2.2 Type of Construction Required

Type A is the most fire-resistant and Type C the least fire-resistant of the Types of construction. It can be seen from the following table that Type A (non-combustible) construction is required for all buildings beyond two or three storeys depending upon the building class.

Table 3.7 – Type of Construction Required (BCA)

Rise in Storeys	Class of Building	
	2, 3, 9	5, 6, 7, 8
1	C	C
2	B	C
3	A	B
4 or more	A	A

3.2.2.3 Fire Resistance of Building Elements (FRL)

The fire resistance level (FRL) means the grading in minutes determined in accordance with Specification A2.3, for the following criteria: structural adequacy; integrity; and insulation, expressed in this order (ABCB, 2007a).

The FRL terminology from the BCA is the same as FRR terminology from NZBC, however these two codes have different approaches to applying these to building elements. While the New Zealand method has separate fire cell rating (F) and structural fire endurance rating (S), the Australian method defines three types of fire-resisting construction: A; B; and C, and tabulates the fire resistance level for various building elements within different classes of building. Types B and C construction are defined more accurately in the BCA clauses, and do not suit tabulating as well as Type A construction can. The following table outlines the fire resistance level required within Type A construction buildings only.

Table 3.8 – FRL Required for Floors within Type A Construction (BCA)

Class of Building	Type A
2, 3, 4	90/90/90
5, 7a, 9	120/120/120
6	180/180/180
7b, 8	240/240/240

See **Appendix B** of this report to view: Table 3 for Type A Construction, Table 4 for Type B Construction and Table 5 for Type C Construction, extracted from Specification C1.1 of BCA (ABCB, 2007a), obtained from webpage:

(www.remedial.com.au/fire-rating-solutions/industry-news.asp)

3.2.2.4 Fire Hazard Properties

The New South Wales variation to the Building Code of Australia (ABCB, 2007a) Clause 1.10 (b) states: Paint or fire-retardant coatings must not be used to make a substrate comply with the required fire hazard properties.

The requirement for maximum fire hazard properties for the ceilings is similar for both NZBC and BCA codes although the numbers for similar situations often differ slightly. The following table gives BCA values.

Table 3.9 – Maximum Fire Hazard Properties for Ceilings (BCA)

Class of Building	Location	Maximum permitted index		
		SFI	SDI	FI
2 to 9	Fire-isolated exits	0	≤ 2	0
2, 3, 9a, 9b	Public corridor	0	≤ 5	–
9a	Patient care	0	≤ 3	–
9b	Theatre or Public hall	≤ 6	≤ 3	–
9b	Fixed seating areas	0	≤ 5	–
2 to 9	General areas	≤ 9	≤ 8 if SFI > 5	–

3.2.2.5 Material Groups Permitted

The BCA has an additional requirement for material groups permitted for within buildings, which are assigned group numbers 1 through 4. Group 1 materials are the best performing materials through to Group 4 materials that are the worst performing materials, with the following definitions (ABCB, 2007a):

Group 1 material is one that does not reach flashover when exposed to 100 kW for 600 seconds followed by exposure to 300 kW for 600 seconds

Group 2 material is one that reaches flashover flowing exposure to 300 kW after not reaching flashover when exposed to 100 kW for 600 seconds

Group 3 material is one that reaches flashover in more than 120 seconds but within 600 seconds when exposed to 100 kW

Group 4 material is one that reaches flashover within 120 seconds when exposed to 100 kW

Group 3 materials typically refer to timber products, Group 2 materials are predominately fire retardant timber and Group 1 materials are non-combustible or near non-combustible, however actual materials require assessment and verification (refer www.timber.net.au).

The following tables give permitted material groups for various location within buildings and these differ according to whether the firecell is sprinklered or not.

Table 3.10 – Ceiling Material Groups Permitted for Unsprinklered Firecells (BCA)

Class of Building	Fire-isolated exits	Public corridors	Specific areas	Other areas
2, 3	1	1, 2	1, 2, 3	1, 2, 3
3, 9a	1	1	1, 2	1, 2, 3
5, 6, 7, 8, 9b	1	1, 2	1, 2	1, 2, 3
9b (not schools)	1	1	1, 2	1, 2, 3

Table 3.11 – Ceiling Material Groups Permitted for Sprinklered Firecells (BCA)

Class of Building	Fire-isolated exits	Public corridors	Specific areas	Other areas
2, 3	1	1, 2, 3	1, 2, 3	1, 2, 3
3, 9a	1	1, 2	1, 2, 3	1, 2, 3
5, 6, 7, 8, 9b	1	1, 2, 3	1, 2, 3	1, 2, 3
9b (not schools)	1	1, 2	1, 2, 3	1, 2, 3
9c	1	1, 2	1, 2, 3	1, 2, 3

3.2.2.6 General Floor Area and Volume Limitations

Floor area is relevant, however volume limitations not as applicable for floor systems.

Table 3.12 – Maximum Area of Fire Compartments (BCA)

Class of Building	Type of Construction Required		
	Type A	Type B	Type C
5, 9b, 9c	8000 m²	5500 m²	3000 m²
6, 7, 8, 9a	5000 m²	3500 m²	2000 m²

3.2.2.7 Protection of Openings

Not applicable for floor systems.

3.2.2.8 Provision for Escape

Not applicable for floor systems.

3.2.2.9 Requirements for Sprinklers

The following table indicates situations where sprinklers are required for deem-to-comply solutions.

Table 3.13 – Sprinkler Requirements (BCA)

Occupancy	Description
All classes	Throughout the whole building if any part of the building has an effective height of more than 25 m
Class 6	In fire compartments where either of the following apply: (a) A floor area of more than 3500 m² (b) A volume of more than 21000 m³
Class 7a	In fire compartments where more than 40 vehicles are accommodated
Class 9c	Throughout the building and any fire compartment containing a Class 9c part
Class 9b	see Part H1

3.2.2.10 Fire Fighting Equipment

Not applicable for floor systems.

3.2.2.11 Smoke Hazard Management

Not applicable for floor systems.

3.3 Acoustic Procedure

Outline typical procedures for floor acoustic design. These are similar for New Zealand and Australia in respect to acoustic ratings, however they differ in use of methods for rating, New Zealand uses American system while Australia has changed to European system.

3.3.1 NZBC – Acoustic Procedure

Typical procedure for floor acoustic design in accordance with NZBC Clauses G6.3.1 and G6.3.2 (DBH, 2005) for habitable spaces of household units:

- Airborne sound transmission class (STC) of floors **no less than 55**
- Impact insulation class (IIC) of floors **no less than 55**

3.3.2 BCA – Acoustic Procedure

Typical procedure for floor acoustic design in accordance with BCA Clause F5.4 (ABCB, 2007a) for separating sole-occupancy units:

- Airborne ($R_W + C_{tr}$) of floors **no less than 50**
- Impact insulation class ($L'_{nT,w} + C_l$) of floors **no more than 62**

USG (2005) advises for most states of Australia the following sound transmission between occupancies:

- Airborne ($R_W + C_{tr}$) of floors **no less than 50, laboratory** tested
- Airborne ($D_{nT,w} + C_l$) of floors **no less than 45, field** tested
- Impact insulation class ($L_{n,w} + C_l$) of floors **no more than 62, laboratory** tested
- Impact insulation class ($L'_{nT,w} + C_l$) of floors **no more than 62, field** tested

3.4 Energy Efficiency Procedure

Floors have some influence on energy efficiency within a building. The NZBC (DHB, 2005) and BCA (ABCB, 2007a) primarily identify the building envelope to protect indoor environment from extremes of outdoor temperatures. Floors can assist with energy efficiency by utilising thermal mass from upper or lower surface of floor system and through passive solar heating of upper surface. Floor coverings will reduce the effectiveness of top surface for each of these as the thermal mass works best if it is exposed to its mode of heating, however ducting to connect with thermal mass is possible.

3.4.1 NZBC – Energy Efficiency Procedure

- Building use/occupancy
- Geographical location for local climate
- Building orientation for managing solar heat gain
- **Thermal mass** of building elements

3.4.2 BCA – Energy Efficiency Procedure

- Building use/occupancy
- Geographical location for local climate
- Building orientation for managing solar heat gain
- **Thermal mass** of building elements
- Utilisation of air movement to assist heating/cooling

4. Assessment of Timber Floor Systems

This chapter provides information and methods for the assessment of timber floor systems. The sections are structural, fire, acoustic and energy efficiency.

4.1 Structural Assessment

1. Literature
2. Design
3. Software
4. Testing
5. Construction

4.1.1 Literature

Literature for the structural assessment of timber floor systems includes the NZBC in New Zealand or the BCA in Australia for principles of compliance, together with the relevant New Zealand and Australian loading and material standards as well as other selected texts.

4.1.1.1 New Zealand Buildings

- New Zealand Building Code
- Structural Design Actions – AS/NZS 1170.0 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.1 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.2 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.3 (SA/SNZ, 2003)
- Structural Design Actions – NZS 1170.5 (SNZ, 2004)
- Timber Framed Buildings – NZS 3604 (SNZ, 1999)
- Timber Structures Standard – NZS 3603 (SNZ, 1993)
- Timber Design Guide (Buchanan, 2007)

4.1.1.2 Australian Buildings

- Building Code of Australia
- Structural Design Actions – AS/NZS 1170.0 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.1 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.2 (SA/SNZ, 2002)
- Structural Design Actions – AS/NZS 1170.3 (SA/SNZ, 2003)

- Structural Design Actions – AS 1170.4 (SA, 2007)
- Residential Timber-Framed Construction, Design Criteria – AS 1684.1 (SA, 1999)
- Residential Timber-Framed Construction, Non-Cyclonic Areas – AS 1684.2 (SA, 2006)
- Residential Timber-Framed Construction, Cyclonic Areas – AS 1684.3 (SA, 2006)
- Timber Structures, Design Methods – AS 1720.1 (SA, 1997)
- Timber Structures, Timber Properties – AS 1720.2 (SA, 2006)
- Handbook for Timber Structures Design Criteria – HB 108 (SA, 1998)

4.1.1.3 Additional Information

- Actions on Structure, General Actions – Part 1-1, Eurocode 1 (CEN, 2002a)
- Actions on Structures Exposed to Fire – Part 1-2, Eurocode 1 (CEN, 2002b)
- Design of Timber Structures, Rules – Part 1-1, Eurocode 5 (CEN, 2004a)
- Design of Timber Structures, Fire Design – Part 1-2, Eurocode 5 (CEN, 2004b)
- Timber Engineering (Thelandersson and Hans, 2003)

4.1.2 Design

Calculation Methods

Structural determination of floor systems is typically carried out by engineering calculation to address the composition of loads for a specific floor span. The Engineer calculates a reasonably accurate dead load and selects the appropriate live load. Dead loads are defined as permanent action and assigned the letter G, while live loads are defined as imposed action and assigned the letter Q. An action is defined as a set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action).

The dead load is comprised of the floor weight including joists, flooring and ceiling. A superimposed dead load for items such as re-locatable wall partitions is often allowed for. Live loads vary depending upon occupancy, for example 1.5 kPa is used for private dwellings and 3.0 kPa for typical offices, with even greater loads for certain applications. The live loads are obtained from the combined Australia and New Zealand Standard AS/NZS 1170.1:2002 (SA/SNZ, 2002) for structural actions.

Load combinations are applied to the floor for various limit states. For floors, the ultimate limit state (ULS) is 1.2G + 1.5Q. The serviceability limit states are typically 1.0G + 0.7Q for short-term deflection and 2.0G + 0.4Q for long term deflection of sawn timber joists. The figure of 2.0 is a creep factor applicable for sawn timber members for load duration of 12 months or more and moisture content of 18% or less at time of loading. Glulam has 1.5 creep factor giving 1.5G + 0.4Q for long term deflection of glulam timber joists.

For more complex structural forms such as timber-concrete composite, finite element analysis is often used to model complex behaviour with correlation to small-scale component tests and full-scale floor tests. Creep factors between 3.0 and 4.0 are presently used until less conservative values can be justified from full-scale long-term load testing.

Span Capacity

There are several competing floor systems on the market, often comprising various material layers to produce a finished floor structure, such as concrete floors on either steel or timber beams or concrete floors on steel tray supported by beams. To aid in the marketing of proprietary floor systems, the manufacturer will typically have tables to assist selection of their floor sections based on common live loads, with the self-weight of the floor system included. It is envisaged that some of the timber and timber-concrete composite floor systems will be marketed in a similar way to gain immediate and ongoing acceptance by specifiers and end users.

Timber-concrete composite floors of various arrangements are currently being tested in several parts of the world. This timber-concrete composite method utilises the benefits of each material with concrete in compression and timber in tension linked by shear connectors to form a rigid composite section. Typically these timber-concrete composite floors can span approximately 9 m which makes them comparable to flat-slab all-concrete floor systems and outperform most steel tray with concrete topping floor systems. The D-Dalle timber-concrete composite system from CBS-CBT in France is expected to achieve spans of up to 18 m (Sandoz, 2004b), which would equal the long-span hollowcore and double “T” concrete floor systems.

Diaphragm Action

Concrete floors are often considered as rigid diaphragms that effectively transmit lateral loads into the lateral load resisting structures. Timber floors have more flexibility in this plane, which must be considered when allocating loads to the various lateral load-resisting structures. Newcombe et al (2009) reported on in-plane experimental testing of one-third scale timber-concrete composite floors and their findings showed that the concrete topping could be modelled as a rigid diaphragm, with deformation occurring at the connectors.

Concrete topping

Concrete topping can be placed as a non-composite topping, which only adds to the dead load without any advantage to the load carrying capacity of the floor system, or designed to act compositely to increase strength and stiffness of the full section. Consider that 65 mm depth of concrete topping at 156 kg/m² is comparable in weight to approximately 300 mm depth of solid timber. If concrete topping weight is added for non-structural performance requirements such as acoustic improvement, then it should be utilised structurally as well in timber-concrete composite action for increased strength and stiffness as well as increased rigidity of diaphragm for distribution of lateral loads.

Two-way span systems

Two-way span action is typically a function of monolithically cast reinforced concrete slab construction where the concrete can be reinforced in both directions, providing better efficiency of the floor section. Solid timber floors products including cross-laminated and stress-laminated timber could be designed for two-way spans depending on longitudinal and transverse direction strength properties of the system, whereas concrete allows more flexibility by selecting the appropriate level of reinforcing. The Refond floor system offers some transverse strength that is beneficial for vibration control and spread of concentrated load, but not enough to provide a balanced two-way span.

Catenary Action

Concrete floor slabs have been shown to perform well in fire temperature conditions due to the catenary action exhibited when deflection is pronounced, particularly for monolithically cast two-way span slabs tied firmly into the surrounding structure. The concrete topping for timber-concrete composite floors might be able to offer some level of catenary action. Timber slabs subjected fire temperatures will not distort to the same extent as concrete, however deflection will increase as loss of section from charring proceeds.

Vibration Control

Vibration criteria is given in Table C1 (and associated note number 10) from AS/NZS 1170.0 (SA/SNZ, 2002a) suggests serviceability limit state criteria by limiting mid-span deflection at less than 1 to 2 mm from 1 kN mid-span load. The associated note states that floor vibration problems are very complex and floors with a fundamental frequency less than 8 Hz and subjected to group rhythmic activity will require special study to ensure in-service functionality. The vibration criteria formula are designed to achieve floor designs with minimum resonance frequencies of around 8 to 10 Hz to prevent springiness associated with bodily oscillations within the frequency range contributing to human discomfort which are normally around 1 to 6 Hz (Bernard, 2009).

Allen and Pernica (1998) recommend minimum floor frequencies of 9 Hz for steel-concrete floors and 13 Hz for light-frame floors when the rhythmic activity is aerobics. For dancing and dining lesser values of 5 Hz for steel-concrete floors and 10 Hz for light-frame floors are given. They advise that stiffness of a light-frame floor is a function of the joist stiffness and the transverse stiffness from the floor deck, cross bridging or blocking. For deflection criteria, they recommend the 2-Part-Curve Formula, and provide the following simple formula to estimate the natural floor frequency for design, where Δ is the total floor deflection of the floor structure.

$$f_n(Hz) = 18/\sqrt{\Delta(mm)}$$

Manufacturers of engineered timber floor systems often apply criteria from AS/NZS 1170.0 (SA/SNZ, 2002a) of 2 mm maximum deflection under 1 kN mid-span load. There is a large difference between this method and the more stringent requirements from Canadian curve especially for longer spans. The Canadian method specifies 2 mm maximum deflection for 3 m spans or shorter, reducing to 0.6 mm maximum deflection for 10 m maximum span, arising from 1 kN applied mid-span load.

An investigation by Bernard (2009) of lightweight timber floors constructed with engineered timber "I" joists concluded that vibration design criteria based on maximum member deflection under a central point load typically provides adequate response for springiness as intended but does not adequately counteract other vibrational disturbances. The subjective disturbances are typically described as shaking of light fittings, windows, cabinets, and crockery in response to nearby footfalls. The research therefore suggests that vibration criteria formula be supplemented with additional criteria to limit dynamic disturbances associated with shaking at higher frequencies.

The following graph shows two similar curves for vibration criteria for engineered timber joist products based on deflection limits for a horizontally span element due to 1 kN of force applied at mid-span for simply supported beams. Points on or below the line are considered acceptable for vibration performance of lightweight engineered timber floors.

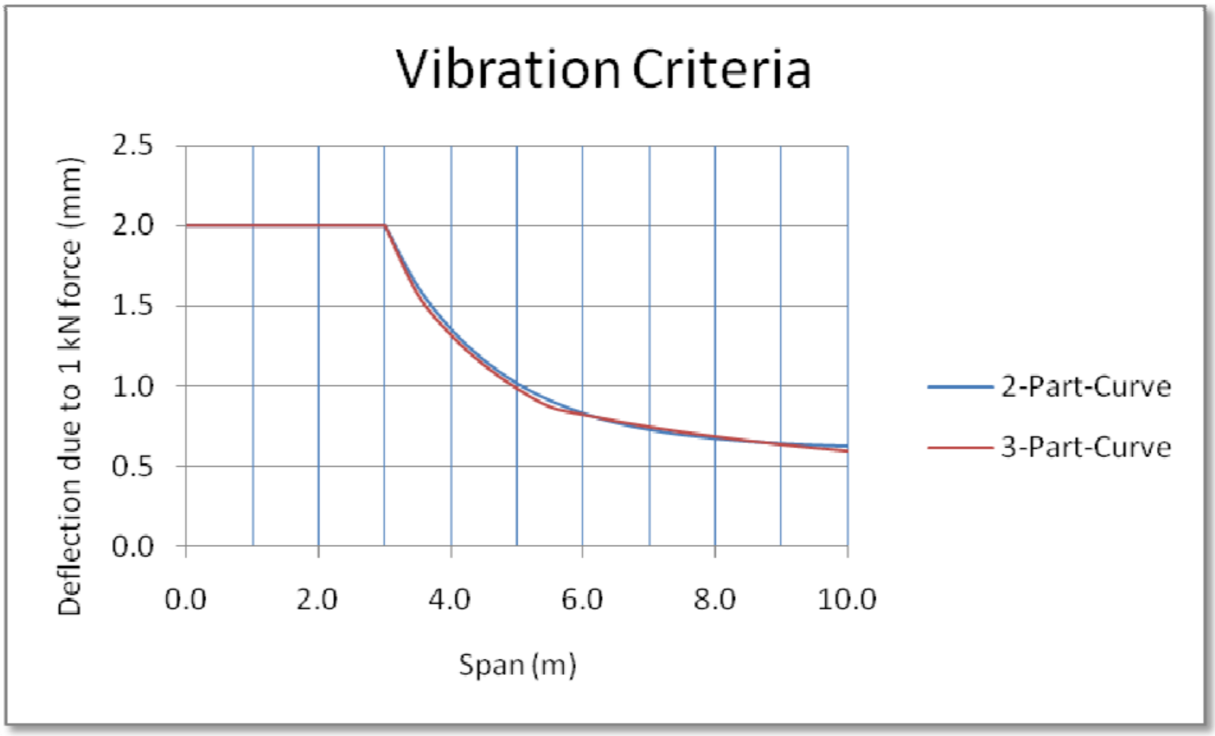


Figure 4.1 – Vibration Criteria for Lightweight Floors

Two curve formulae are given. The formula found in the National Building Code of Canada is typically referred to. Both of these curves will give almost identical results within the 10 m maximum range.

2-Part-Curve Formula

2.0 mm	curve from zero to 3.0 m
$06 + 2.5e^{-0.6(L-2)}$	curve from 3.0m to 10.0m

3-Part-Curve Formula

2.0 mm	curve from zero to 3.0 m
$8/l^{1.3}$	curve from 3.0 m to 5.5 m
$2.55/l^{0.63}$	curve from 5.5 m to 10.0 m

4.1.3 Software

Proprietary Member Selection Software

Design IT Series 4 (CHH, 2009) is a computer program to assist selection of LVL and "I" beam products specific to this manufacturer.

NP Design NZ LVL 10 (Nelson Pine, 2003b) is a computer program to assist selection of LVL products specific to this manufacturer.

Design-In-Hyne (Hyne, 2009) is a computer program to assist selection of "I" beam products specific to this manufacturer.

Commercial Member Selection Software

QuickDesign (HR Design Group, 2009) is a computer program to assist selection of timber floor joist products from a range of Manufacturers plus glulam and sawn timber joists.

Lintels and Beams Calculator (BRANZ, 2009) is an online computer program that performs the design of timber and steel beam members, with a small fee payable for each design.

Note: Lintels and Beams Calculator was used to determine capacity of 600 x 63 LVL at 300 mm centres, with a resulting span of 8.4 m obtained by trial and error. In comparison DesignIT gave span of 10.4 m and NP Design gave span of 9.9 m for the same member size and centres.

4.1.4 Testing

Structural Testing

Deflection of timber and timber-concrete composite floor systems is of particular interest because of the inherent long-term creep affect which concrete also displays to a much lesser degree. The creep factor varies for different materials and is typically 2.0 for sawn timber floor joists and LVL floor joists.

By comparison a creep factor of 1.5 is typically used for glulam floor joists. The creep factor also varies for different floor systems. Timber-concrete composite floor design at the University of Canterbury currently assumes creep values between 3.0 and 4.0 for provide conservative calculations until further testing indicates applicable values.

Full-scale physical tests of complete floor assemblies in conjunction with smaller scaled sub-assembly and component tests are carried out to provide correlation to design methods and finite element analysis or to allow derivation of empirical formulae for a range of studied elements.

4.1.5 Construction

Timber Advantage

The advantages of timber in floor systems are many. Timber has a high strength-to-weight ratio, which results in lighter building elements. A lighter building allows for smaller footings and less seismic restraint. For prefabricated floor elements this means lighter haulage weight to site and easier handling on site. Timber has an excellent aesthetic appeal in situations where it can be left visible and it has ecological benefits as a sustainable material. To compete with other floor systems, the timber options should be comparable in cost and constructability, and provide the necessary fire and acoustic protection.

Working with timber on site can be carried out by Carpenters while concrete and steel floor systems often require specialist installers or additional trades on site. The prefabrication of timber floor systems is likely to increase so that less installation time is required on site which will ultimately lead to on-site labour cost savings. The efficiency and economics of prefabrication should be considered as well as improved quality control.

The typical construction sequence for solid timber joist floor systems: position floor joists to span between load bearing walls or beams, install blocking between joists, lay and fix timber sheet flooring on top of joists, fix plasterboard ceiling to underside of joists. Insulation can be included in the void to provide sound or thermal insulation between consecutive floors. For timber-concrete composite floor systems, there is the added aspect of concrete topping, which can be cast in-situ using formwork or arrive with timber as a complete unit. Permanent formwork, typically plywood or steel tray, is often used to save time on site although reusable formwork can be considered.

Construction loads need to be assessed particularly where poured concrete topping is required. Care must be taken to concrete is not placed in large heaps that might overload the floor. A construction uniformly distributed load is often assumed between 1.5 and 2.5 kPa to allow for workers, wet concrete and stacked materials.

Durability

Careful selection of materials and good detailing is required to ensure structural elements can effectively achieve their intended service life. This durability is a key aspect that requires attention to encourage the move to timber floors systems. Moisture is a particular concern for timber elements, with recent cases of rotting timber attributed to moisture ingress through the building envelope. Particleboard is more susceptible to water damage than solid wood, with significant swelling upon contact with moisture and break down over time with continued exposure to moisture.

Post Service

The latest research into multi-storey timber buildings at the University of Canterbury has identified other ideas to explore. Their aim is to devise systems made from modular components to provide modular construction using a series of parts that can "plug and play" with option of replacing damaged parts after a seismic event. This is similar to the Lego bricks concept where a variety of predefined parts can be easily connected together to form relatively complex constructions. This concept also aids the deconstruction of a building for reconstructing elsewhere or reuse of parts to create a different building form. Beyond the reuse of building elements, timber can be recycled into new items such as furniture, or used in wood-fired boilers to provide alternative energy supply.

4.2 Fire Assessment

1. Literature
2. Design
3. Software
4. Testing
5. Construction

4.2.1 Literature

Literature for the fire assessment of timber floor systems includes the NZBC in New Zealand or the BCA in Australia for principles of compliance, together with the relevant New Zealand and Australian loading and material standards as well as other selected texts.

4.2.1.1 New Zealand Buildings

- New Zealand Building Code
- Timber Structures Standard – NZS 3603 (SNZ, 1993)
- Timber Design Guide (Buchanan, 2007)

4.2.1.2 Australian Buildings

- Building Code of Australia
- Timber Structures, Design Methods – AS 1720.1 (SA, 1997)
- Timber Structures, Timber Properties – AS 1720.2 (SA, 2006a)
- Timber Structures, Fire Resistance of Timber Members – AS 1720.4 (SA, 2006b)

4.2.1.3 Additional Information

- International Fire Engineering Guidelines (IFEG, 2005)
- Enclosure Fire Dynamics (Karlsson and Quintiere, 2000)
- Handbook of Fire Protection Engineering (SFPE, 2008)
- Fire Protection Handbook (NFPA, 2008)
- Fire Engineering Design Guide (Spearpoint, 2008)
- Structural Design for Fire Safety (Buchanan, 2001)
- Actions on Structures, Exposed to Fire, Part 1-2, Eurocode 1 (CEN, 2002b)
- Design of Timber Structures, Structural Fire Design, Part 1-2, Eurocode 5 (CEN, 2004b)
- Masters Thesis by O'Neill (2009)

4.2.2 Design

Calculation Methods

Buchanan (2001) describes the fire design procedure for timber elements. Fire resistance of a structural member of structural systems must exceed the fire severity requirements. Verification of fire resistance is calculated in three domains, time, temperature or strength. The temperature domain is not applicable for timber because there is no critical temperature for timber strength in comparison with steel that progressively weakens as temperature increases. Instead, timber is verified in the time domain or strength domain to structural collapse.

Heavy Timber Construction

Heavy timber is typically classified by members with approximately 90 mm minimum for the smaller dimension. NZS 3603 (SNZ, 1993) details a residual timber cross-section method based on charring rate β = 0.65 mm/min and loss of section including rounding of the fire exposed corners. Lie (1977) made reference most important factors governing the charring of wood, are the density of the wood, its permeability, and moisture content. A charring rate β = 0.60 mm/min was given as a reasonable average. Extreme values were also offered, β = 0.80 mm/min when wood is light and dry and β = 0.40 mm/min when wood is moist and dense.

Research by Lane (2005) recommended two options for predicting the fire performance of New Zealand manufactured Radiata Pine LVL exposed to post-flashover fires. The simpler recommended method is to use the experimentally obtained charring rate β = 0.72 mm/min and calculate residual strength of reduced timber cross-section with normal temperature timber properties for strength calculation. Alternatively, use the effective cross-section method based on charring rate β = 0.65 mm/min plus 7 to 9 mm of zero-strength layer of LVL below the char line with normal temperature timber properties for strength calculation.

Cachim and Franssen (2010) have assessed charring rates using finite element modelling software SAFIR for comparison with those found in Eurocode 5 Part 1-2 (2005). They have determined that charring rate of timber is affected by many factors including density, permeability and composition based on wood species coupled with moisture content and direction of heat transfer, parallel or perpendicular to the grain.

Light Timber Construction

Light timber construction typically refers to framed construction of stud walls and joist floors using members with approximately 36 mm minimum for the smaller dimension. Fire protection of light timber framed wall and floor assemblies is generally achieved with gypsum plasterboard linings. In timber joist floor assemblies the gypsum plasterboard provides the ceiling, joints are stopped and paint applied to give the finished surface. To increase ceiling fire resistance, fire-rated gypsum plaster boards are used, which come in several thicknesses and are applied as single or multiple layers.

Floor Fire Resistance

Early work by Lawson and Webster (1951) makes the distinction between fire endurance and fire resistance. Fire endurance was defined as the time taken to collapse (stability), with additional criteria for fire resistance, the ability of the ceiling to resist flame penetration (integrity) and limited temperature rise on the upper surface (insulation).

Exposed timber ceilings do not comply with New Zealand Building Code surface finish requirements even when sprinklers are installed. Surface finish requirement for exposed timber ceilings, timber beams are exempt. Exposed wood and wood products thicker than 1.0 mm in walls and ceilings are deemed to increase the fire hazard category if sprinklers are not present where the required F or S rating is 60 minutes or more.

Sprinklers are typically required for life protection purposes when occupancy numbers or height of building dictates their use. Firecells equipped with sprinklers remove the surface finish requirement for walls however ceilings are not exempt. Possible reasons for non-reduction of requirements for ceiling linings are: sprinklers designed to extinguish fire below not fire above; ceiling is always present even if walls are remote, say in larger rooms; ceilings will ignite at lower heat flux because rising heat adds to the concentration of heat flux with the opposite applicable for floor surfaces.

Intumescent coatings can be applied to timber products to reduce the spread of flame index (SFI) and smoke developed index (SDI). Typically, the coatings are a paint pigment finish and there few transparent products to allow a natural timber finish. Poon and England (2003) refer to AS 1720.4 requirement for fire-retardant treatment, can only be assessed by testing in accordance with AS 1530.4 and that such treatment is not likely to materially improve the fire resistance of timber. Intumescent coatings for timber are typically designed to reduce the spread of flames over a surface (White, 2008). There is a specific clause particular to the State of New South Wales that states: Paint or fire-retardant coatings must not be used to make a substrate comply with the required fire hazard properties (Clause NSW C1.10 (b) of BCA, 2007).

Fire resistance of wall and floor assemblies can be evaluated using numerical models or simplified formulas. Bénichou, N. & Sultan, M.A. (2000) evaluated various calculation models and commented on the need for further research into various material characteristics to improve these, by comparison with physical fire tests. Typically these models had a narrow range of application. Cramer (1995) describes a finite element numerical model SAWFT for predicting the fire endurance of gypsum wall board protected wood assemblies, with additional work required to further develop the model.

Schleifer (2006) has proposed a new design method for fire resistance of timber-framed construction with gypsum board protective layers, based on physical models for the gypsum boards and their relative position when two or more layers are used. A thermal calculation model using finite element analysis was used to provide calculations based on results of fire tests for validation. Frangi, Erchinger and Fontana (2008) found accelerated charring rates of timber floor joists occurred after the protective gypsum board ceiling falls off due to the presence of higher temperatures when the timber is exposed to the fire.

Component Additive Method (CAM)

According to AF&PA (2004), the original method for calculating fire endurance ratings was developed in the early 1960's by the Fire Test Board of the National Research Council of Canada. An extensive series of fire tests on timber stud walls and timber joist floors resulted in the following rules by Harmathy (1964), see this document for extended explanation of each rule.

Ten Rules of Fire Endurance Rating

Rule 1 *– The "thermal" fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurances characteristic of the individual layers when exposed separately to fire.*

Rule 2 *– The fire endurance of a construction does not decrease with the addition of further layers.*

Rule 3 *– The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.*

Rule 4 *– The farther an air gap or cavity is located from the exposed surface, the more beneficial is its effect on the fire endurance.*

Rule 5 *– The fire endurance of a construction cannot be increased by increasing the thickness of a completely enclosed air layer.*

Rule 6 *– Layers of materials of low thermal conductivity are better utilized on that side of the construction on which fire is more likely to happen.*

Rule 7 *– The fire endurance of asymmetrical constructions depends on the direction of heat flow.*

Rule 8 *– The presence of moisture, if it does not result in explosive spalling, increases the fire endurance.*

Rule 9 *– Load-supporting elements, such as beams, girders, and joists, yield higher fire endurances when subjected to fire endurance tests as parts of floor, roof, or ceiling assemblies than they would when tested separately.*

Rule 10 *– The load-supporting elements (beams, girders, joists, etc.) of a floor, roof, or ceiling assembly can be replaced by such other load-supporting elements which, when tested separately, yielded fire endurances not less than that of the assembly.*

4.2.3 Software

Simplified Element Analysis

Firetest (Collier, 2000a) is a computer program to which allows extrapolation of timber joist floor spans based on fire test results for typical floor spans. There is an accompanying manual (Collier, 2000b) and an earlier BRANZ report (Collier, 1991) detailing fire tests of timber framed walls and floors that form the basis for this software.

Advanced Finite Element Modelling

SAFIR, developed by Franssen (2006), is a non-linear finite element computer program for thermal analysis and structural analysis.

4.2.4 Testing

Fire Testing

Sultan, Séguin and Leroux (1998) have presented the results of 32 standard fire resistance tests conducted on full-scale floor assemblies, most of which were timber floor systems typically with gypsum board protective ceilings. Sawn timber joists and engineered "I" joists systems were compared with variables including: the number of gypsum board layers, joist spacing and resilient channel spacing and applied loads. Of note is their test of floors with added concrete topping, which had reduced fire resistance. It was determined that the concrete topping increased the thermal resistance, resulting in increased heating rate of the gypsum board causing this to fall off earlier. These test used steel joists, however the effect of concrete topping would occur with timber joists as well.

Recently fire tests on timber-concrete composite floor units have been conducted at BRANZ facilities by (O'Neill, 2009). Full-scale LVL members were tested using 4.0 m maximum span catered for by the BRANZ fire rig. The design live load was 2.5 kPa, which is factored by 0.4 for the fire load condition and factored again to account for the difference in length to ensure that the applied moment in the fire test is the same for full-length floor unit. The test specimens were subjected to the ISO 834 design fire (ISO, 1999).

The first test was conducted on two adjacent floor units comprising 65 mm concrete on 17 mm plywood sheathing on 2/300 x 63 mm LVL timber beams for each unit. The nominated design span was 5.0 m to calculate applied test load of 1.56 kPa. The second test was conducted on two adjacent floor units comprising 65 mm concrete on 17 mm plywood sheathing on 2/400 x 63 mm LVL timber beams for each unit. The nominated design span was 7.0 m to calculate applied test load of 3.06 kPa.

The two floor units for each test allowed two different shear connectors to be tested, one with toothed steel plates sandwiched between the timber beams and projecting into the concrete, the other with a timber notch and bolt detail. From the results of these tests, O'Neill (2009) has written a spreadsheet giving fire resistance for various beam size and floor spans within the scope of the tested units. Fire resistance of up to two hours was included in his spreadsheet. The pressed metal plate exhibited greater stiffness, while the notch and bolt connection was easier to construct. Failure was attributable to the reduced timber section.

4.3 Acoustic Assessment

1. Literature
2. Design
3. Software
4. Testing
5. Construction

4.3.1 Literature

Literature for the acoustic assessment of timber floor systems includes the NZBC in New Zealand or the BCA in Australia for principles of compliance, together with the relevant New Zealand and Australian loading and material standards as well as other selected texts, plus a range of ASTM and ISO standards on following pages.

New Zealand Buildings

- New Zealand Building Code (DBH, 2005)
- Timber Design Guide (Buchanan, 2007)

Australian Buildings

- Building Code of Australia (ABCB, 2007a)

Additional Information

- Engineering Noise Control: Theory and Practice (Bies and Hansen, 2009)
- Noise Control in Buildings: A Practical Guide for Architects and Engineers (Harris, 1994)
- Detailing for Acoustics (Lord and Templeton, 1996)

4.3.1.1 Australian Acoustic Measurement

Airborne Sound – Australia

AS 1191	Acoustics – Method for **laboratory** measurement of **airborne** sound transmission insulation of building elements (SA, 2002)
AS 2253	Methods for **field** measurement of the reduction of **airborne** sound transmission in building (SA, 1979)
AS/NZS 2499	Acoustics – Measurements of sound insulation in buildings and of building elements – **Laboratory** measurement of room-to-room **airborne** sound insulation of a suspended ceiling with a plenum above it (SA/SNZ, 2000)
AS ISO 140.4	Acoustics – Measurement of sound insulation in buildings and of building elements, Part 4: **Field** measurements of **airborne** sound insulation between rooms (SA, 2006)

Impact Sound – Australia

AS ISO 140.6	Acoustics – Measurement of sound insulation in buildings and of building elements, Part 6: **Laboratory** measurements of **impact** sound insulation of floors (SA/ISO, 2006)
AS/NZS ISO 140.7	Acoustics – Measurement of sound insulation in buildings and of building elements, Part 7: **Field** measurements of **impact** sound insulation of **floors** (SA/SNZ/ISO, 2006)
AS/NZS ISO 140.8	Acoustics – Measurement of sound insulation in buildings and of building elements, Part 8: **Laboratory** measurements of the reduction of transmitted **impact** noise by floor coverings on a **heavyweight** standard **floor** (SA/SNZ/ISO, 2006)

Rating of Sound Insulation – Australia

AS/NZS ISO 717.1	Acoustics – **Rating** of sound insulation in buildings and of building elements, Part 1: **Airborne** sound insulation (SA/SNZ/ISO, 2004)
AS ISO 717.2	Acoustics – **Rating** of sound insulation in buildings and of building elements, Part 2: **Impact** sound insulation (SA/ISO, 2004)

4.3.1.2 European Acoustic Measurements:

Airborne Sound – Europe

ISO 140.3	Acoustics: measurement of sound insulation in buildings and of building elements, Part 3: **Laboratory** measurements of **airborne** sound insulation of building elements (ISO, 1995)
AS ISO 140.4	*Same as previous Australian section.*

Impact Sound – Europe

AS ISO 140.6	*Same as previous Australian section.*
AS/NZS ISO 140.7	*Same as previous Australian section.*
AS/NZS ISO 140.8	*Same as previous Australian section.*
ISO 140.11	Acoustics: measurement of sound insulation in buildings and of building elements, Part 11: **Laboratory** measurements of the reduction of transmitted **impact** sound by floor coverings on **lightweight** reference **floors** (ISO, 2005)

Rating of Sound Insulation – Europe

AS/NZS ISO 717.1	*Same as previous Australian section.*
AS ISO 717.2	*Same as previous Australian section.*

Alternative (recently introduced) Method of Transmission Loss Measurement

ISO 15186.1	Acoustics: measurement of sound insulation in buildings and of building elements using **sound intensity**, Part 1: **Laboratory** measurements (ISO, 2000)
ISO 15186.2	Acoustics: measurement of sound insulation in buildings and of building elements using **sound intensity**, Part 2: **Field** measurements (ISO, 2003)
ISO 15186.3	Acoustics: measurement of sound insulation in buildings and of building elements using **sound intensity**, Part 3: **Laboratory** measurements at **low frequencies** (ISO, 2002)

4.3.1.3 North American Acoustic Measurement

Airborne Sound – North America

ASTM E90-09	Standard Test Method for Laboratory Measurement of **Airborne** Sound Transmission Loss of Building Partitions and Elements (ASTM, 2009a)
ASTM E336-09	Standard Test Method for Measurement of **Airborne** Sound Attenuation between Rooms in Buildings (ASTM, 2009b)

Impact Sound – North America

ASTM E492-09	Standard Test Method for Laboratory Measurement of **Impact** Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine (ASTM, 2009c)
ASTM E989-06	Standard Classification for Determination of **Impact** Insulation Class (ASTM, 2006a)

Rating of Sound Insulation – North America

ASTM E413-04	Classification for Rating Sound Insulation (ASTM, 2004)
ASTM E1574-98	Standard Test Method for Measurement of Sound in Residential Spaces (ASTM, 2006b)

Alternative (recently introduced) Method of Transmission Loss Measurement

ASTM E2249-02	Standard Test Method for **Laboratory** Measurement of Airborne Transmission Loss of Building Partitions and Elements Using **Sound Intensity** (ASTM, 2008)

4.3.2 Design

Acoustic Summary

Floors are very important barrier to reduce sound transmission by resisting airborne and impact sound from adjacent rooms. There are two types of sound/noise transfer considered when assessing floors:

- Airborne sound
- Impact sound

There are other sound/noise aspects that are also considered in building design but are beyond the scope of this report:

- Flanking sound
- Reflected sound

Airborne sound

Airborne sound propagates initially through the air before it enters the structure. Typical irritating airborne sound sources in include speech, radio, television, music systems, home theatre, coughing and noises from animals (USG, 2005).

Impact sound

Impact sound originates from the impact of one object on another. Irritating impact sound in buildings normally originates with objects in contact with the floor such as chairs scraping, items dropping and footsteps. Hard floor surfaces including tile, timber and vinyl accentuate these sounds (USG, 2005). Impact sound refers to the sound produced when a short-duration impulse, such as a footfall, acts directly on a structure (Lord and Templeton, 1996).

Flanking Sound

Flanking sound is a combination of the direct and indirect sounds that travel through the adjoining building elements, both airborne and impact. Care with detailing of floor and wall junctions is required to ensure flanking paths are negligible as the indirect sound paths compromises the direct path acoustic protection. Measurements are recorded in adjacent receiver rooms from sound in the source room. The receiver rooms are above, below, beside and diagonally adjacent.

Reflected Sound

Bies and Hansen (2009) textbook, Chapter 8, *Partitions, Enclosures and Barriers,* gives a detail account of sound reflection within the room of origin, whereas this research report primarily focuses on sound transmission through floors beyond the room of origin rather than sound effects within the room of origin. Soft furniture and carpet on the floor will absorb some of the reflected sound, with further sound reduction achieved using acoustic ceiling panel by through the use of sound absorbing material or by porous panels.

Calculation Methods

There are two methods for measuring and rating acoustic insulation. The North American method prescribed in ASTM standards are used in New Zealand and the European Method prescribed in ISO standards has been recently adopted in Australia. The sound frequency range for ASTM method is 125 Hz to 4000 Hz in 1/3 octave bands, and for ISO method is 100 Hz to 3150 Hz in 1/3 octave bands.

Warnock (2004) compares the ASTM and ISO methods for rating impact sound rating. Each of these methods use the standardised tapping machine as well as the same frequency and reference. The curve fitting procedure differs with ASTM rounding to the nearest decibel, while ISO rounds to nearest 0.1 dB and applies a maximum deficiency of 8 dB. It is this "8 dB rule" causes significant rating differences, without its application the two ratings IIC and L_n are related, subtract either value from 110 to obtain the other.

Impact sound is far more complicated to measure, rate and control than airborne sound (Warnock, 1999). Most of the energy of impact sounds on concrete floors transmits at high frequency compared with low frequency sounds through lightweight joist floors. This low frequency noise, falling below the minimum frequency range measured for rating of impact insulation, is often cited as annoying noises such as "thump", "boom" or "thud". Warnock (2004) suggests it would be ideal if both ASTM and ISO could change to a new rating system to resolve confusion between current rating systems. His recommendation is for C100 rating, which denotes the energy sum from 100 to 2500 Hz minus 15 dB, and advises C50 rating would be impractical to implement.

A study by Chung et al (2006) into impact sound resistance of lightweight floor systems separated results into two frequency ranges, a summary of this report was presented by Emms et al (2006). They note that the mid to high impact frequency range between about 100 Hz to 3150 Hz can be reasonably well determined while the low impact frequency range less than about 100 Hz is problematic. Emms and Nebel (2007) extended upon the 2006 study by investigating sustainable materials to replace insulation while still offering similar level of acoustic improvement.

Warnock and Birta (1998) report on testing of over 190 floor specimens for fire resistance and sound insulation. Their executive summary points out which elements in a floor system have an effect on airborne and impact sound. An associated report by Warnock and Birta (2000) contains sound transmission and impact insulation in 1/3 octave bands when detailed sound insulation spectra is required. A recent report by Warnock (2005) which is a continuation of the earlier floor testing to include another 67 floor assemblies, with the results used to refine a regression model for estimating STC and IIC, available as computer program SOCRATES (NRCC, 2005).

From Kolb (2008) page 270: *Primarily owing to their low weight per unit area, the low stiffness of the load bearing construction and significant sealing and connection problems, timber floors have inherent disadvantages when it comes to sound insulation, unless they have been specifically designed to satisfy acoustic requirements. And in terms of impact sound insulation, it is the low frequencies that are especially problematic (muffled vibrations). There is a certain relationship between impact sound and airborne sound insulation. This explains the guiding principle that if the impact sound insulation of a suspended timber floor is adequate, the airborne sound insulation will generally be adequate too. Both airborne sound insulation and impact sound insulation are affected by flanking transmissions common in buildings.*

4.3.3 Software

Modelling using software initially requires correlation with physical tests to confirm scope and accuracy of the program.

Simplified Acoustic Software

SOCRATES, a pneumonic for, Sound Classification Rating Estimator, is software by developed within the Institute for Research in Construction, National Research Council Canada NRCC (2005). This program estimates STC and IIC Ratings for common floor constructions (and STC for common wall constructions). Choices are limited to force correct acoustical design.

Commercial Acoustic Software

INSUL is an acoustic software package developed by Marshall Day Acoustics (2009) for predicting the sound insulation of walls, floors, ceilings and windows. The programme can make good estimates of the Transmission Loss (TL) in 1/3 octave bands and Weighted Sound Reduction Index (STC or R_W) for use in noise transfer calculations. Like any prediction tool, INSUL is not a substitute for measurement. However, comparisons with test data indicate that INSUL reliably predicts STC values to within 3 dB for most constructions.

ENC, is software from Casual Systems (2009) and is based on the previous editions of Bies & Hansen book *Engineering Noise Control: Theory and Practice*, 3rd Ed. (2003)

4.3.4 Testing

4.3.4.1 ASTM Method

Airborne Sound – ASTM

Sound transmission Class (STC) is a single number rating derived from measured values of transmission loss in accordance with classification E413-04 (ASTM, 2004), *Determination of Sound Transmission Class*. It provides an estimate of the performance of a partition in certain common sound insulation situations (BIA, 2005). A higher STC value is better for laboratory and field ratings.

Impact Sound – ASTM

Impact insulation class (IIC) is a single number rating derived from measured values of normalized impact sound pressure levels in accordance with method E492-09 (ASTM, 2009c), *Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine, Annex A1*. It provides an estimate of the impact sound insulating performance of a floor-ceiling assembly (BIA, 2005). A higher IIC value is better for laboratory and field ratings.

4.3.4.2 ISO Method

Airborne Sound – ISO

R_W Weighted Sound Reduction Index

D_{nT} Standardised Sound Level Difference

$D_{nT,w}$ Weighted Standardised Sound Level Difference

The definitions following are from Lord and Templeton, 1996:

R_W Weighted sound reduction index is a weighted single-figure descriptor of the sound reduction performance of a partition measured in laboratory conditions.

D_{nT} Standardised sound level difference is used to assess airborne sound insulation between rooms in buildings.

$D_{nT,w}$ Weighted standardised sound level difference is a weighted single-figure rating from field measured values.

The ISO method also provides a means of modifying the **R_W** values using correction factors **C** and **C_{tr}**. These are added to RW, however as these factors are typically negative, with downgrading of **R_W** as a result (Bies and Hansen 2009).

C Correction factor is used for incident sound consisting of living activities (talking, music, radio, TV), children playing, medium and high speed rail traffic, highway road traffic greater than 80 km/hr, jet aircraft at short distances and factories emitting mainly medium to high frequency sound (Bies and Hansen 2009).

C_{tr} Correction factor is used for incident sound consisting of urban road traffic, low speed rail traffic, propeller driven aircraft, jet aircraft at long distances, disco music and factories emitting mainly low to medium frequency sound (Bies and Hansen 2009).

R_W (C; C_{tr}) Laboratory rating, **higher** number is better.

$D_{nT,w}$ (C; C_{tr}) Field rating, **higher** number is better.

Impact Sound – ISO

L Impact Sound Level

$L_{n,W}$ Weighted Normalised Impact Sound Level

$L'_{nT,w}$ Weighted Standardised Impact Sound Level

The definitions following are from Lord and Templeton, 1996:

L Impact sound level is the sound pressure level measure in a one-third octave band when a standard tapping machine is operating of the floor above the room.

$L_{n,W}$ Weighted normalised impact sound level is a weighted single-figure descriptor obtained from one-third octave band values of the normalised impact sound **L_n** (laboratory) or **L'_n** (field).

$L'_{nT,w}$ Weighted standardised impact sound level is a weighted single-figure field measurement standardised to a reverberation time of 0.5 seconds.

The ISO method also provides a correction factor **C_I** for impact noise.

$L_{n,W}$ (C_I) Laboratory rating, **lower** number is better.

$L'_{nT,w}$ (C_I) Field rating, **lower** number is better.

It is worth noting that ISO impact noise rating is better for lower values compared with ISO airborne and ASTM impact and airborne. There is an approximate relationship between ISO **L_n** and ASTM **IIC**:

L_n is approximately equal to 110 minus **IIC**

4.3.5 Construction

Direct and Flanking Noise Protection

A comprehensive report by Quirt, Nightingale and King (2006) addresses direct and flanking paths of airborne and impact noise. They provide tables to take into account various floor, ceiling and wall constructions as well as various floor coverings. The document includes specific guidance and associated construction drawings.

Product Substitution

An important not made by the authors was that: *many of the materials were specific proprietary products, which are identified in individual assembly specifications. It should be understood that significant variations must be expected if "generic equivalents" are incorrectly chosen, or details are changed.*

Improving the sustainability of timber-framed floors has been investigated by Emms and Nebel (2007) to reduce environmental impacts without compromising the acoustic performance of the floor. Streamlined environmental life cycle assessments were performed on a number of floors.

The following tables were obtained from Warnock (1999):

Table 4.1 – Approximate IIC Ratings for 150 mm Concrete Slab

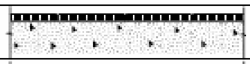
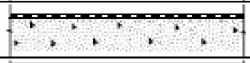
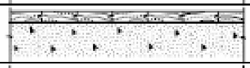
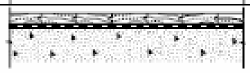
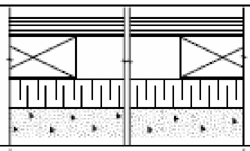
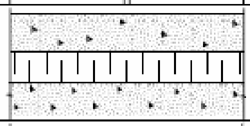
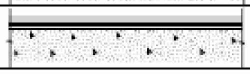
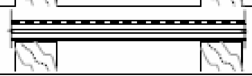
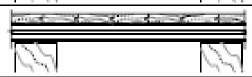
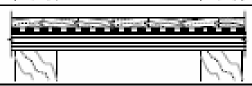
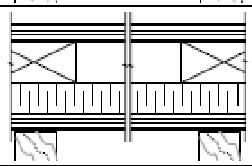
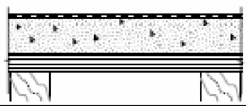
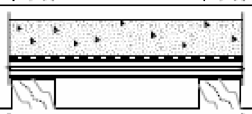
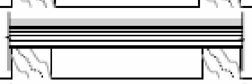
Table 1		Topping	IIC
I-1		None, or ceramic or marble tiles	28
I-2		Vinyl flooring	35-40
I-3		Hardwood flooring	30-35
I-4		9-mm-thick hardwood on 6-mm-thick resilient layer	45-50
I-5		16-mm plywood or OSB on 40- x 90-mm wood strapping on 25-mm mineral fibre board	50-55
I-6		35-mm concrete on 25-mm mineral fibre board	60-65
I-7		Carpet and underlay	75-85

Table 4.2 – Approximate IIC Ratings for Timber Joist Floors

Table 2		Topping	IIC
II-1		Ceramic or marble tiles	40
II-2		Vinyl flooring	47
II-3		Hardwood flooring	47
II-4		9-mm-thick hardwood on 6-mm-thick resilient layer	47
II-5		16-mm plywood or OSB on 40- x 90-mm wood strapping on 25-mm mineral fibre board	55-58
II-6		Resilient flooring on 35-mm concrete	52
II-7		35-mm concrete on resilient layer	55-65
II-8		Carpet and underlay	75-85
II-9		Carpet and underlay on 35-mm concrete	>85

4.4 Energy Efficiency Assessment

1. Literature
2. Design
3. Thermal Mass
4. Software

4.4.1 Literature

Literature for the energy efficiency assessment of timber floor systems includes the NZBC in New Zealand or the BCA in Australia for principles of compliance.

New Zealand Buildings

- New Zealand Building Code (DBH, 2005)

Australian Buildings

- Building Code of Australia (ABCB, 2007a)

Additional Information

- Guide to the Building Code of Australia (ABCB, 2007b)
- Masters Thesis by Perez (2008)
- MAF Report by John et al (2008)

4.4.2 Design

Energy efficiency design for buildings is typically modelled using computer software as the building characteristics and effects from occupancy and internal systems are considered as a whole. Aspects of the building relevant to floor systems that affect energy performance are:

- **Thermal mass** of building elements
- Geographical location for local climate
- Building orientation and shape
- Heat gains from solar radiation

Other aspects for consideration beyond floor aspects include:

- Thermal resistance and air-tightness of the building envelope
- Utilisation of air movement to assist heating/cooling
- Building use/occupancy
- Artificial lighting requirements
- Heat gains from services

4.4.3 Software

ALF, short for Annual Loss Factor is a free online aid to the thermal design of houses by BRANZ (2007). ALF 3.2 is a verification method for determining the Building Performance Index (BPI), which can be used to show compliance with the Energy Efficiency Clause H1 of the New Zealand Building Code.

4.4.4 Thermal Mass

Thermal mass describes the ability of a material to store and release heat. This is beneficial on the building environment as it reduces the requirement for heating and air-conditioning. The thermal envelope comprising exterior walls, windows and roof receives significant attention, however thermal mass is specifically mentioned in H1.3.3. of the NZBC (DHB, 2005).

From NZ Wood website (www.nzwood.co.nz): the volume of wood has to be double that of concrete as the volumetric heat capacity of wood is approximately 1000 kJ/m^{3}K and concrete is approximately 2100 kJ/m^{3}K. However, five times the surface area of wood to concrete for equivalent temperature transfer, due to thermal effusivity of wood versus that of concrete is approximately 350 J/m^{2}Ks^{½} and 1800 J/m^{2}Ks^{½} respectively.

As the floor area of a given building is constant, a concrete floor or concrete topping will provide increased thermal transfer compared with a solid timber slab. Comparison between full concrete floor system and timber-concrete composite floor system, 225 mm thick concrete compared with 65 mm thick concrete topping gives 3.5 times greater volume for heat retention for thicker concrete. Comparing solid timber solid timber floor system and timber-concrete composite floor system, 300 mm thick timber compared with 65 mm thick concrete topping gives 1.9 times greater volume for heat retention for timber, however heat transfer is 5.1 times less.

Approximate dead weight for the previous floor systems without ceilings, insulation, floor finishes or superimposed loads are:

- 5.4 kPa for 225 mm thick solid concrete
- 2.3 kPa for 65 mm thick concrete on timber joists
- 1.5 kPa for 300 mm thick solid timber

It is likely that timber-concrete composite floor systems will be utilised in future buildings due to their moderate weight combined with ability to provide stiff diaphragm action along with other structural, fire and acoustic advantages. The solid timber option is the lightest of these, with resulting benefit to other parts of the structure, however fire, acoustic and vibration performance must be considered.

5. Types of Floor Systems

This chapter includes a range of timber and timber-composite floor systems typically used or under development in New Zealand and around the world.

5.1 *Timber Floor Systems*

Chapters 5, 6, 7 and 8 have been indexed to aid location of the same timber floor system in each section, for example **Lignatur (4.6)** can be found at:

5.4.6 in Chapter 5 – Types of Floor Systems

6.4.6 in Chapter 6 – Structural Performance of Timber Floor Systems

7.4.6 in Chapter 7 – Fire Performance of Timber Floor Systems

8.4.6 in Chapter 8 – Acoustic Performance of Timber Floor Systems

Research on new timber and timber-concrete composite floor systems listed is currently being conducted in several countries, with the aim to gain greater clear floor spans. Several countries are focussing on various alternatives of timber-concrete composite floor systems, with research conducted in New Zealand, Australia, Canada, United States, Austria, Germany, Italy, Sweden, United Kingdom and others. A wide array of timber to concrete connection systems have been explored in these studies.

Timber floor systems currently employed in New Zealand are generally sawn timber or LVL floor joists for typical timber house construction. For longer span floors, there is an increased use of LVL joists plus a variety of engineered timber "I" joists and parallel chord timber floor trusses. Glulam is sometimes used for bespoke floor solutions. Recently introduced timber floor systems include Potius, a stressed-skin panel, that has the option of top and bottom skins, or top skin only. It can also carry a concrete topping, either with composite action or without. See website (www.potius.co.nz) for further information.

Hebel 75 mm PowerFloor is an aerated concrete panel which can be laid onto timber floor joists, has additional weight compared with traditional timber floors with particleboard or plywood flooring nailed directly to timber joists. This added weight reduces the span length for a particular timber joist layout, however LVL and glulam will allow for increased spans. There was also the launch of website (www.flexus.co.nz) in 2010 to promote the Flexus floor product, which comprises a 30 mm engineered cementitious composite (ECC) topping on Pryda Span parallel timber chord trusses. This Potius floor and Flexus floor products arrives on site as prefabricated units.

A similar base range of timber floor solutions are available in Australia, the only notable addition to the list is TECbeam, which is a prefabricated “I” beam with timber chords and a press-formed steel web. This is quite similar to a product previously marketed in New Zealand product called Twinaplate, however the Twinaplate product did not have the large circular web openings that TECbeam does, allowing for electrical and mechanical services to pass though.

Recent testing of stressed-skin floor panels has been conducted at the University of Technology Sydney (UTS) in Australia, along with a national focus on span calculations for plywood box beams for use as floor joists. An extensive programme of timber-concrete composite testing is currently being conducted at the University of Canterbury (UC) in New Zealand, including structural loading, fire testing and long-term deflection.

Solid Timber Joists

1.1 Sawn Timber Joists

1.2 Glue Laminated (Glulam) Timber Joists

1.3 Laminated Veneer Lumber (LVL) Joists

Timber "I" Joists

2.1 HyJOIST

2.2 LumberworX

2.3 Hyne

Parallel Timber Chord Trusses

3.1 Pryda Longreach

3.2 Pryda Span

3.3 Posi-STRUT

Recently Introduced Timber Floor Systems

4.1 Hebel 75 mm PowerFloor

4.2 Flexus Floor

4.3 TECbeam

4.4 TECslab

4.5 Potius

4.6 Lignatur

4.7 Wenus

4.8 O'Portune

4.9 D-Dalle

4.10 Structural Insulated Panel (SIP)

Under Development Timber Floor Systems

5.1 Timber-Concrete Composite (TCC)

5.2 Plywood Box Beam Joists

5.3 Stressed-Skin Panel (SSP)

5.4 Cross-Laminated Timber (CLT)

5.5 Vertical Nailed Plank (VPN)

5.6 Stress-Laminated Timber (SLT)

5.7 Refond Floor

5.1.1 Sawn Timber Joists

The most common domestic timber flooring solution in New Zealand is sawn timber joists with timber particleboard flooring above and Gibraltar board ceilings below. Sawn timber joists have limitations of product length and span capability. These sawn timber joists are typically sized using New Zealand Standard NZS 3604 (SNZ, 1999), however it is possible to gain a bit more length by calculation and greater lengths using laminated veneer lumber (LVL) members.

5.1.2 Glue Laminated (Glulam) Timber Joists

Glulam timber is a premium timber product and due to its higher cost is often reserved for situations where it will remain visible, often as exposed roof rafters. Prior to the introduction of LVL, longer floor spans have been achieved using glulam joists, particularly for aesthetic reasons where these joists were to remain visible. Several Manufacturers have recently joined to market New Zealand Engineered Glulam under the name STRATALAM, see website (www.stratalam.co.nz).

The stiffness performance of standard glulam GL8 is similar to that of higher sawn timber grades with a smaller 1.5 creep factor applied, compared with 2.0 for sawn timber and LVL. Increased spans are achievable from the deeper/wider sections that are available. Glulam members can be produced with various dimensions, standard widths include 65 mm for joists as well as 90 mm, 135 mm and 180 mm for larger beams.

Increased strength grades are available in New Zealand, with GL10 commonly produced and GL12 can be specified although costs increase significantly to produce this higher grade. Higher grades have been attempted overseas, of note is the Herculle beam concept proposed for GL40 and GL45 glued structural elements, using multi-orientation glulam timber for high performance in bending (Sandoz, 2004a).

5.1.3 Laminated Veneer Lumber (LVL) Joists

Sawn timber joists are increasingly being replaced with LVL members as this engineered material offers increased strength, better dimensional stability, longer and deeper product dimensions, thus allowing longer traditional style floor spans to be achieved. Similar to other timber engineered joists and trusses, LVL can be used with Hebel or concrete toppings by specific design. The two major LVL producing companies in New Zealand are Carter Holt Harvey and Nelson Pine, whose products are marketed under the respective names of Hyspan LVL and NelsonPine LVL.

5.2 Timber “I” Joists

The three main timber “I” joist products supplied in New Zealand are HyJOIST, LumberworX and Hyne. A similar product TECbeam is a timber chord “I” joist product from Australia, which has a press-formed steel web, whereas the three others have timber webs, either plywood or orientated strand board (OSB).

König and Källsner (2006) modelled floor assemblies with timber “I” joists for fire resistance. The thermal analysis was conducted using SAFIR software, which is able to predict failure of the gypsum board using predefined criteria. The structural analysis was carried out with an Excel spreadsheet CSTFire, which utilised the temperature output from the heat transfer calculations.

5.2.1 HyJOIST®

HyJOIST "I" beams have LVL flanges and plywood webs. There are eight sections available with depths of 200 mm, 240 mm, 300 mm, 360 mm or 400 mm, and flange widths can be 45 mm, 63 mm or 90 mm depending on depth of section. HyJOIST was previously marketed under the name Hybeam. This was changed to better identify the primary use of this product. Futurebuild Technical Note 83-06-03 (CHH, 2006a) advises suitability of HyJOIST joist floors with heated concrete topping.

The following photo and cross-section were obtained from NZ Wood website (www.nzwood.co.nz):

Figure 5.1 – Photo and Cross-Section of HyJOIST® Floor "I" Joists

5.2.2 LumberworX®

LumberworX "I" beams have LVL flanges and plywood web. There are eight sections available with depths of 200 mm, 240 mm, 300 mm or 360 mm, and flange widths either 63 mm or 88 mm.

The following cross-sections were obtained from LumberworX (2009):

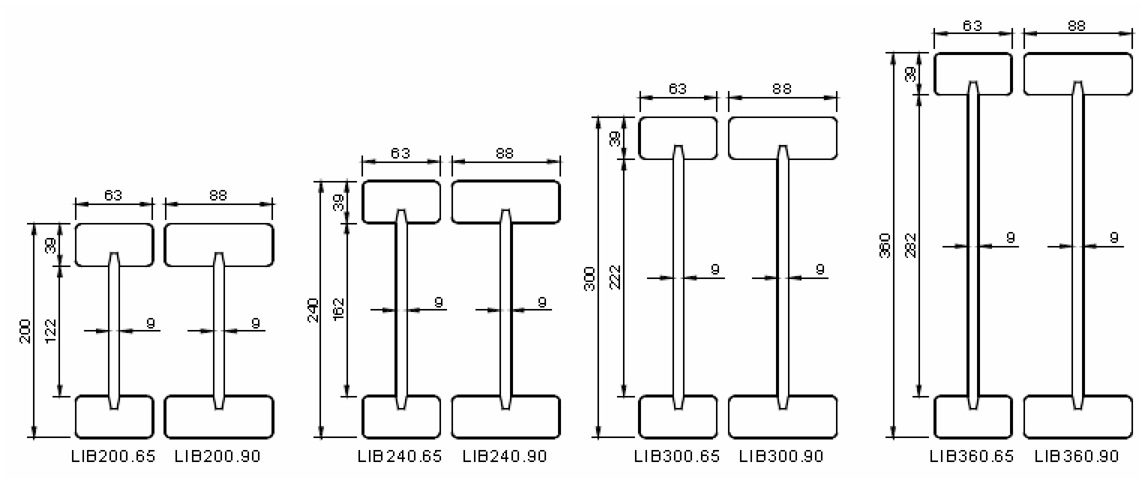


Figure 5.2 – Cross-Section of LumberworX® "I" Joists

"*I" Beams require approximately 50 percent less wood than is needed for a solid wood beam of the same strength,* (www.lumberworx.co.nz).

5.2.3 Hyne®

Hyne "I" beams have sawn timber flanges and an oriented strand board (OSB) web. There are four sections available with depths of 200 mm, 245 mm, 300 mm or 360 mm. The flange width for this brand is 90 mm. This product, now marketed by Engineered Timber Solutions in New Zealand, was previously called Origin Hyne "I" Beam.

The following photo and cross-section were obtained from Hyne Australia website (www.hyne.com.au):

Figure 5.3 – Photo and Cross-Section of Hyne® Floor "I" Joists

Hyne "I" Beams are less than half the weight of comparable solid timber sections, (www.hyne.com.au).

5.3 Parallel Timber Chord Trusses

5.3.1 Pryda® Longreach

Pryda Longreach trusses have sawn timber top and bottom chord flanges and sawn timber diagonal members joined with steel tooth plate connectors. There are five sections available with depths of 250 mm, 300 mm, 350 mm, 400 mm or 450 mm. The flanges are 90 mm by 45 mm sawn timber members with optional strength grades of machine stress grade MSG8 or MSG12.

The following photo was obtained from Pryda NZ website (www.pryda.co.nz):

Figure 5.4 – Photo of Pryda® Longreach Floor Trusses

5.3.2 Pryda® Span

Pryda Span trusses have sawn timber top and bottom chord flanges and steel diagonal joined with steel tooth plate connectors. There are three sections available with depths of 260 mm, 310 mm or 410 mm. The flanges are 90 mm by 45 mm sawn timber members with optional strength grades of machine stress grade MSG8 or MSG12.

The following photo was obtained from Pryda NZ website (www.pryda.co.nz):

Figure 5.5 – Photo of Pryda® Span Floor Trusses

5.3.3 Posi-STRUT™

Posi-STRUT trusses are similar to Pryda Span, with sawn timber top and bottom chord flanges and steel diagonal joined with steel tooth plate connectors. There are several sections available with depths varying between 197 mm and 603 mm. For most of these depths there are differing flange sizes that can be selected, in all there are fifteen Posi-STRUT floor truss options for commercial floors plus six for domestic floors. Additionally, there is machine stress grade MSG8 or MSG10 option for flanges.

Photo obtained from Startek Enterprises website (www.startekenterprises.com):

Figure 5.6 – Photo of Posi-STRUT™ Floor Trusses

Photo obtained from A. C. Roof Trusses website (www.acrooftrusses.co.uk):

Figure 5.7 – Floor Cassettes with Posi-STRUT™ Floor Trusses

5.4 Recently Introduced Timber Floor Systems

5.4.1 Hebel® 75 mm PowerFloor™ on Timber Joists

Hebel is an aerated autoclaved concrete (AAC) product, with a standard dry density range of 500 kg/m³ to 650 kg/m³. The Hebel 75 mm PowerFloor is constructed with steel mesh reinforced AAC panels that are 75 mm thick, which are laid onto timber joists. Width dimension 600 mm, length dimension 1800 mm.

The maximum span for this system on timber joists is approximately 3.5 m for standard timber joists or approximately 4.5 with LVL joists of similar size. Greater spans are achievable with deeper LVL or glulam joists by specific structural calculation.

The following photo and graphic were obtained from Hebel Australia website (www.hebelaustralia.com.au):

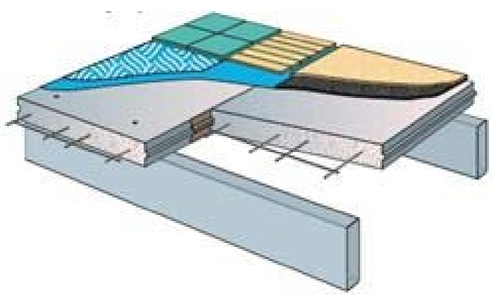



Figure 5.8 – Photo and Graphic of Hebel® PowerFloor™ on Timber Joists

5.4.2 Flexus™ Floor

Flexus floor is a new floor system developed by Reid by utilising Pryda Span floor trusses combined with a high-performance fibre-reinforced engineered cementitious composite (ECC) 30 mm precast topping cast integral with the timber floor trusses. Pryda and Reid are both owned by Illinois Tool Works (ITW) Inc.

The following photos were obtained from Reid (2009):

Figure 5.9 – Photo of Flexus™ Floor developed by Reid™

Figure 5.10 – Photo of Flexus™ Floor Lifted into Position

5.4.3 TECbeam®

TECbeam is a prefabricated "I" beam with timber chords and a press-formed steel web. It is similar to Twinaplate product previously marketed in New Zealand product, however TECbeam has large circular web openings allowing for electrical and mechanical services to pass through.

The following photo was obtained from TECbeam website (www.tecbeam.com.au):

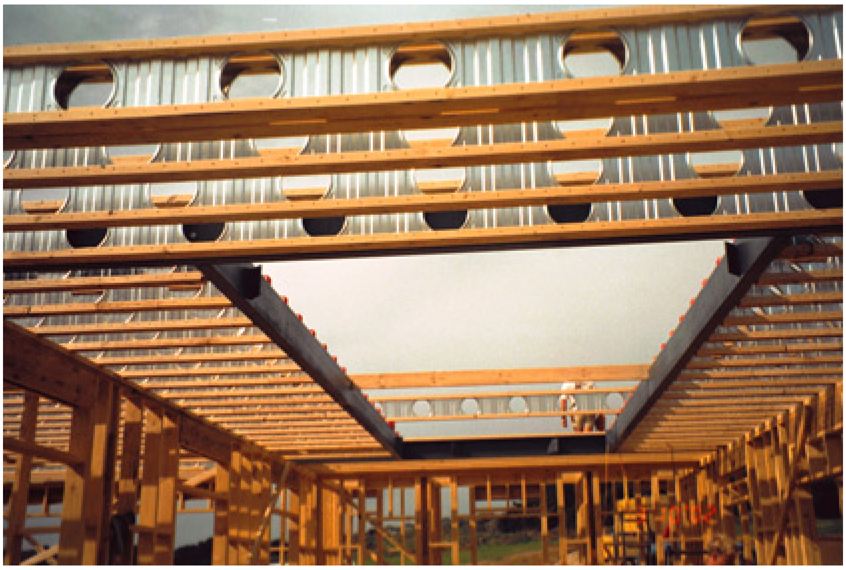


Figure 5.11 – Photo of TECbeam® Joists

5.4.4 TECslab®

TECslab is a combination of TECbeam joists with Hebel 75 mm floor panels. An alternative TECslab floor design involves pouring a lightweight concrete topping over plywood flooring supported by TECbeam joists (www.tecbeam.com.au).

The following photo was obtained from TECbeam website (www.tecbeam.com.au):

Figure 5.12 – Photo of TECslab® Floor System

5.4.5 Potius^{TM}

Potius is a stressed-skin panel (SSP) timber floor system, prefabricated in Nelson, NZ. The lightweight nature of these floor units allows fast installation. There are specifically designed by Potius for each new job, either one-sided "T" beam arrangement or two-sided "I" beam arrangement often with inclusion of flange stiffeners. Recent Potius applications have also included concrete topping that either as dead load or designed to act compositely.

The following photos was obtained from Potius website (www.potius.co.nz):

Figure 5.13 – Photo of Potius^{TM} Floor Units

5.4.6 Lignatur®

Lignatur of Switzerland has an advanced range of timber floor products. There are two modular floor systems, box elements and surface elements for floors and roofs shown in photographs below. The box elements are 200 mm wide by maximum 12 m long and can allow for fire protection of up to 60 minutes. The surface elements are 514 mm wide by maximum 12 m long and can allow for fire protection of up to 90 minutes. Both of these systems can offer levels of soundproofing, sound absorption and heat insulation. Further information on these products and photos is located in technical workbook (Lignatur, 2009).

Figure 5.14 – Photo of Lignatur® Box Element

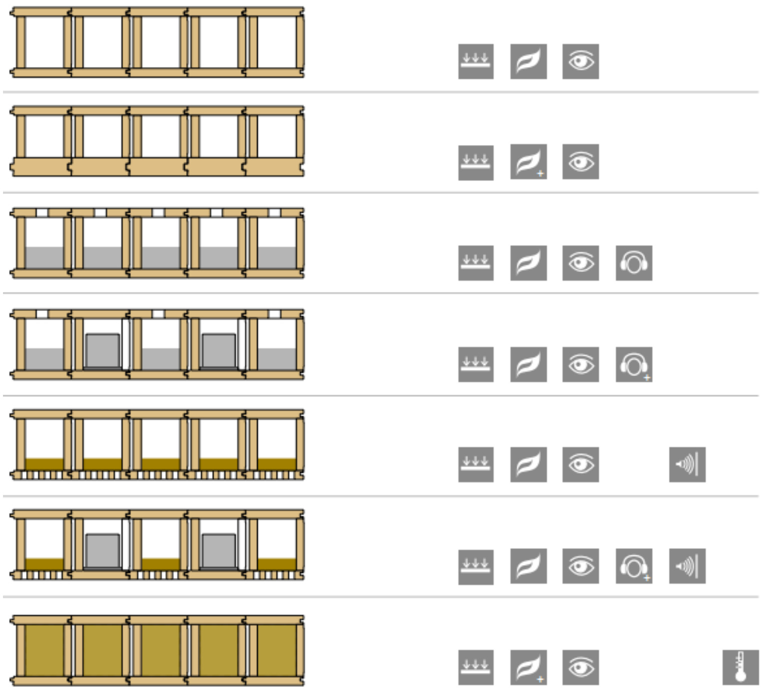


Figure 5.15 – Graphic of Lignatur® Box Element Options

Figure 5.16 – Photo of Lignatur® Surface Element

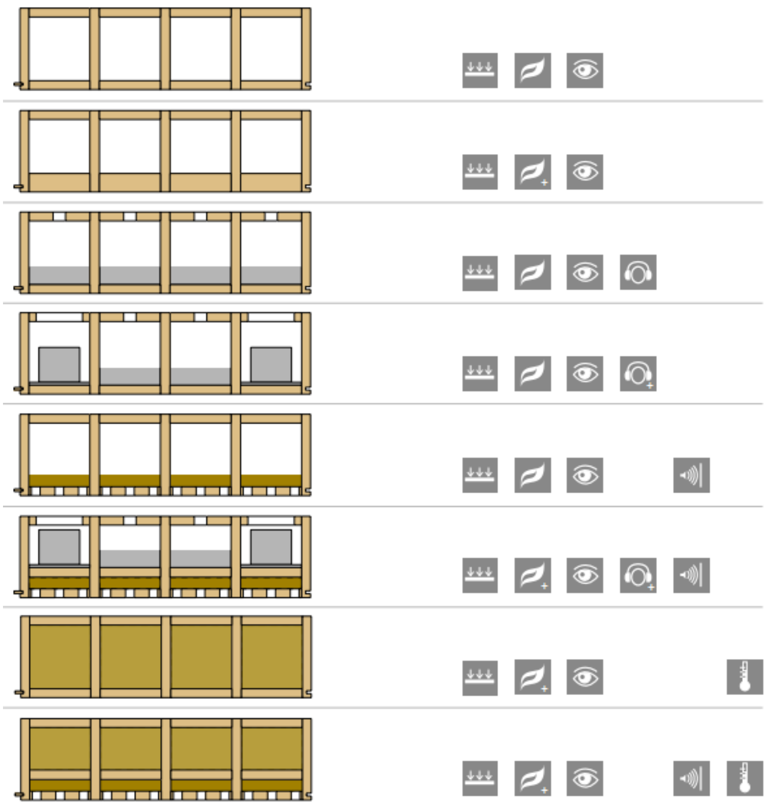


Figure 5.17 – Graphic of Lignatur® Surface Element Options

The icons refer to:

Statics Fire resistance Aesthetics Soundproofing Room acoustics Heat insulation

5.4.7 Wenus®

Wenus panel is marketed as a floor and wall solution. This product is constructed with sawn timber or LVL to form this "W" shape folded plate element that provides carrying capacity and a strong visual pattern. Further information on this product can be found in technical description by CBS-CBT (2009c).

The following photo and cross-section were obtained from CBS-CBT (2009c):

Figure 5.18 – Photo of Wenus® Finished Ceiling

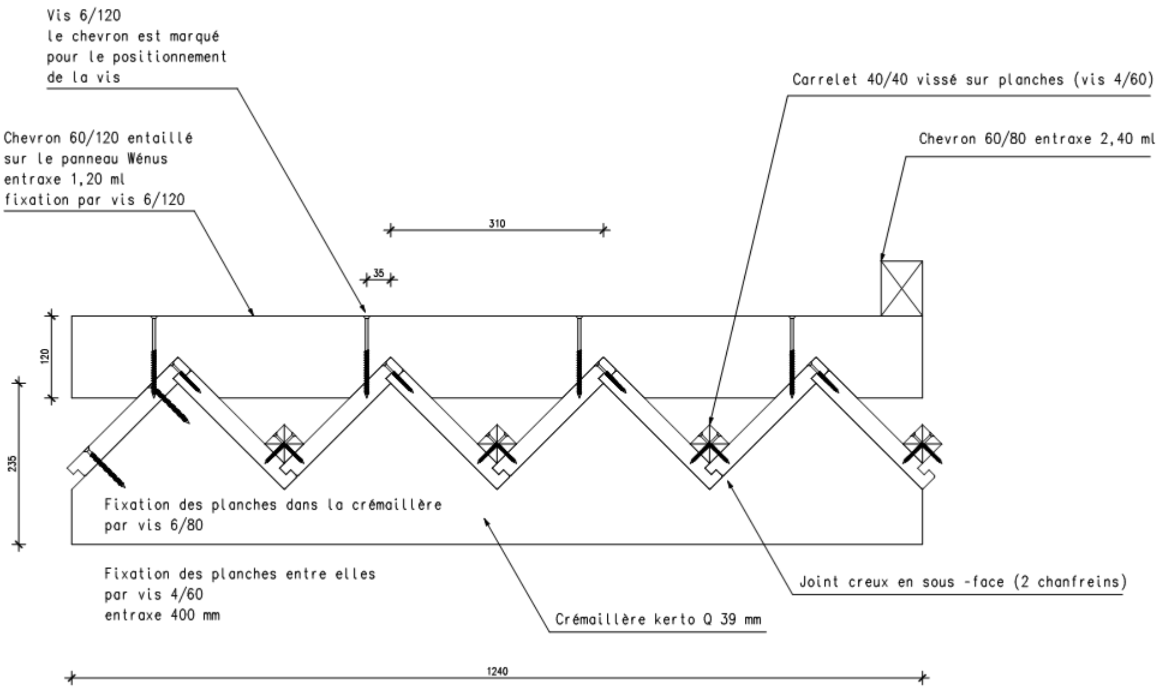


Figure 5.19 – Cross-Section of Wenus® Floor System

5.4.8 O'Portune®

O'Portune is marketed as a floor solution. This product is constructed with sawn timber staggered vertically to increase the depth of inertial for greater span capacity. Flooring, either LVL slab or OSB is laid across the tops to form a level upper surface. The resulting soffit presents a striking visual pattern. Further information on this product can be found in technical description by CBS-CBT (2009b).

The following photo and cross-section were obtained from CBS-CBT (2009b):

Figure 5.20 – Photo of O'Portune® Finished Ceiling

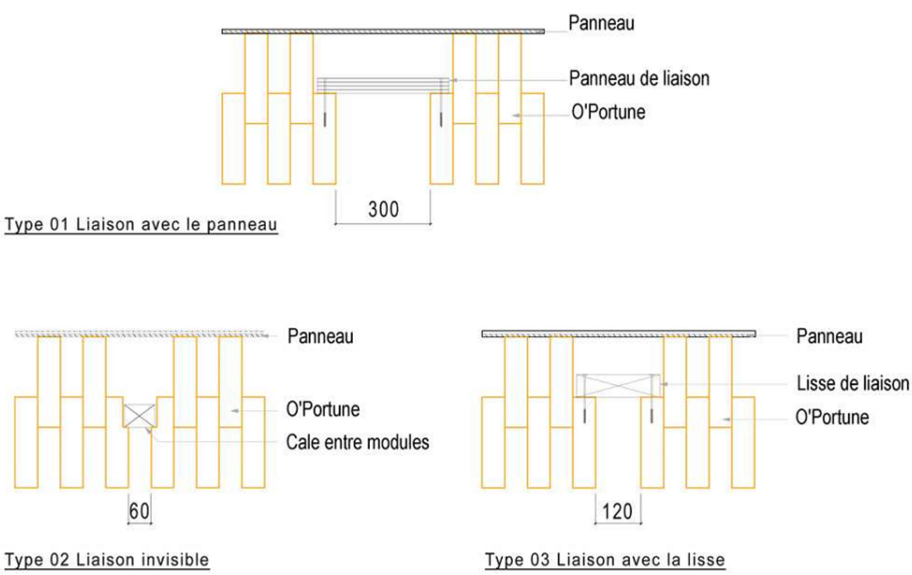


Figure 5.21 – Cross-section of O'Portune® Floor System Variants

5.4.9 D-Dalle®

D-Dalle floor solution is essentially the O'Portune system described above with a composite concrete topping to further increase the floor strength and to assist with fire and acoustic resistance. Further information on this product can be found in technical description by CBS-CBT (2009a). It was previously estimated by Sandoz (2004b) that this timber-concrete composite system could span up to 18 m, and figure below shows load test conducted on a 16 m specimen.

The following photo was obtained from CBS-CBT (2009a):

Figure 5.22 – Photo of D-Dalle® TCC Structural Floor Test

5.4.10 Structural Insulated Panel (SIP)

Structural insulated panels, commonly referred to as SIPs are particularly prevalent in North America. They are described as sandwich panel with timber top and bottom and foam in between. The timber is often oriented strand board (OSB) or plywood and the foam is commonly expanded polystyrene. The primary uses for this product are as roofs and walls, with prefabrication providing speedy erection on site. They are suitable as an insulated lower level floor but not suitable for mid-floors due to span limitations and low acoustic performance for a basic unit without a ceiling.

APA (1993) provides a good reference for the structural design and fabrication of plywood sandwich panels. White (1993) advised that unprotected sandwich panels acting as a load bearing members do not provide satisfactory fire performance. Kermani (2006) noted that while structural insulated panel are a widespread form of construction in the North America, the concept was only recently introduced into the United Kingdom. See Innovaré Systems website (www.innovaresystems.co.uk) for UK manufacturer of SIPs floor cassette product.

The following photo and detail were obtained from Premier Building Systems website (www.pbssips.com):

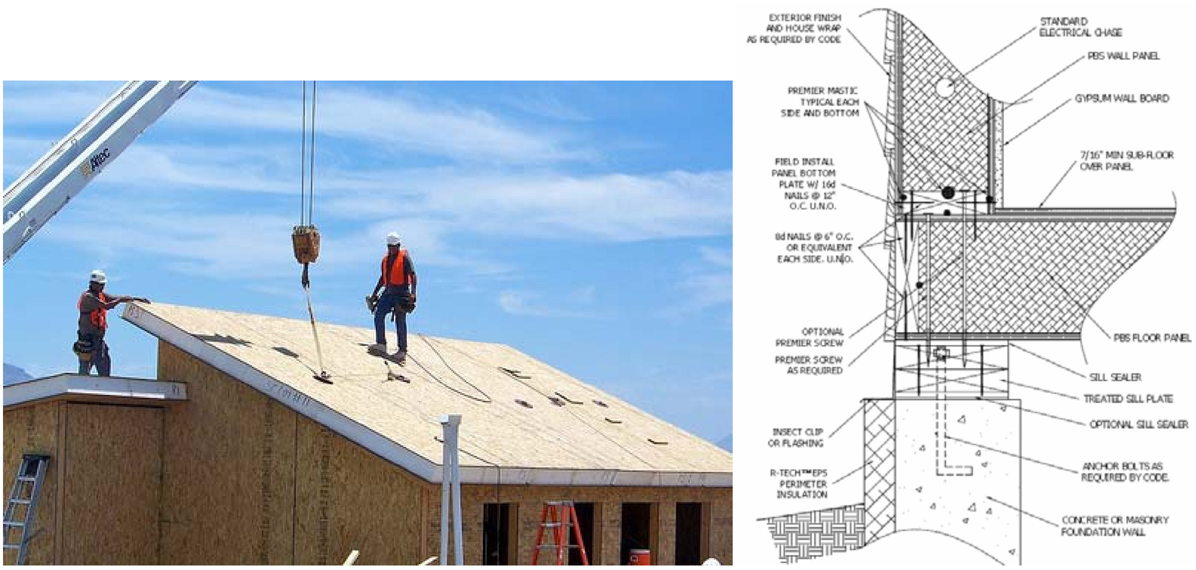


Figure 5.23 – Photo and Detail of Structural Insulated Panels (SIPs)

The following details were obtained from R-Control Australasia website (www.au.rcontrol.com):

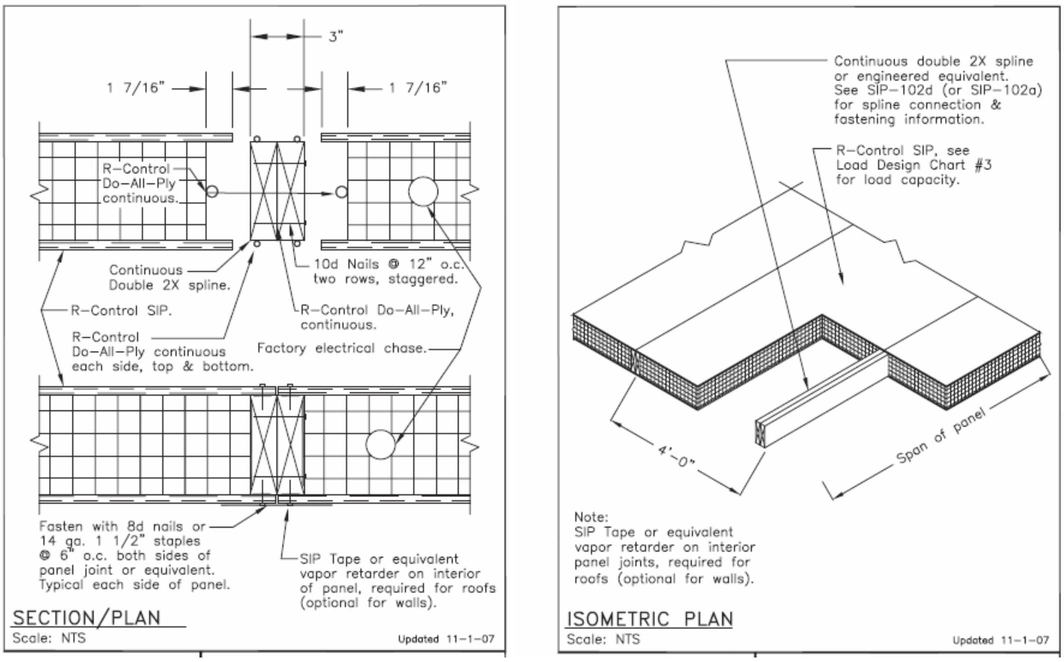


Figure 5.24 – Structural Insulated Panel Floor Details

5.5 Under Development Timber Floor Systems

5.5.1 Timber-Concrete Composite (TCC)

There is considerable focus on timber-concrete composite floor systems, with current ongoing research into many variants across several counties. The original concept for these floors comes from a retrofit technique devised in Europe to upgrade existing timber floors in historic buildings. The composite floor utilises the structural attributes of each material, timber in tension and concrete in compression. The timber has a high strength-to-weight ratio leading to lighter floors and the concrete topping aids with fire resistance and acoustic separation.

The following figures were obtained from Lukaszewska (2009):

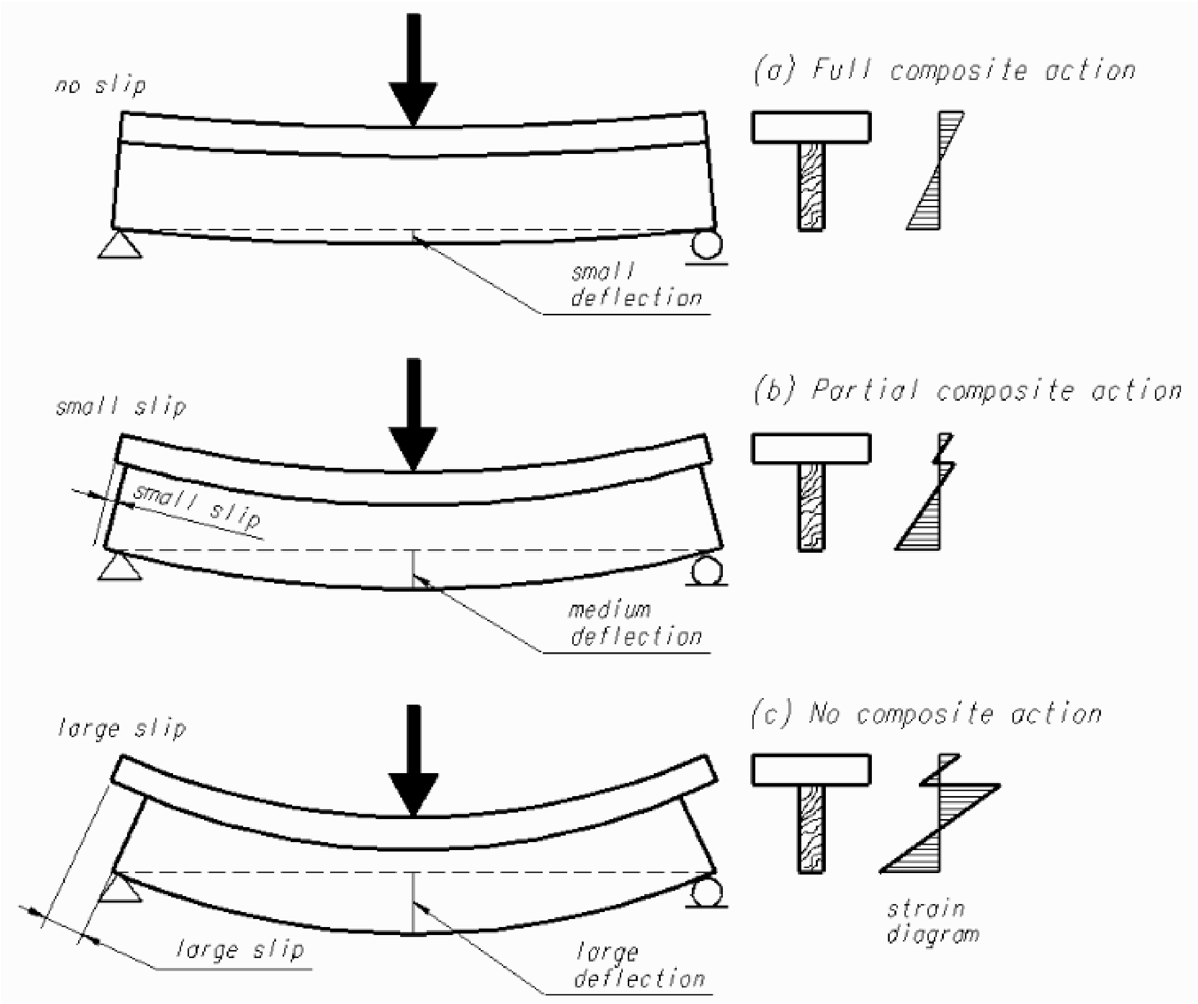


Figure 5.25 – Full, Partial and Non-Composite Action Diagrams

Origins of Timber-Concrete Composite

Ancient buildings across Europe often comprise a layout of rectangular or round timber beams with an inert cast in-situ mortar slab on top (Faggiano et al, 2009). Restoration of these buildings has lead to the replacement of topping to form a timber-concrete composite section to increase strength and stiffness capacity for vertical loads and to function as a rigid diaphragm for horizontal loads. This paper by Faggiano et al (2009) addresses finite element modelling of innovative steel collar connectors to achieve timber-concrete composite action for improving the existing timber floors of historical buildings.

According to Holz Beton Verbund website (www.hbv-systeme.de), the first attempts to combine the materials wood and concrete were carried out in the 1920's and 1930's. The reason for these early developments of the wood-concrete composite components was mainly the lack of steel material available during that time. Otto Schaub was the first inventor in Germany to apply for a patent that consists of a timber-concrete composite element. In recent years many researchers and engineers all over the world have been working on the optimisation of wood-concrete composite systems. The main focus has been to develop a shear connector that allows a rigid connection between wood and concrete and at the same time provide a ductile behaviour of the composite system under ultimate loading conditions.

Ceccotti (1995) describes the timber-concrete composite floor system as a structurally efficient section, being rigid and light at the same time, by using the concrete in compression and the timber in tension. Ceccotti (2002) outlines the main features of timber-concrete composite floors. They are lighter than comparable concrete systems and more efficient due to timbers high strength-to-weight ratio. They have greater strength, greater stiffness and increased damping than traditional timber systems. They have improved airborne and impact noise insulation and they have good fire resistance, with the concrete slab acting as an effective barrier and the large timber ribs offer predictable rates of charring.

Deam, Fragiacomo and Buchanan (2008) experimented on various methods for shear connection between LVL timber beams and concrete topping. The tests showed that a concrete plug formed by square notches or circular holes in the LVL combined with a screw central to the hole provided the best stiffness, strength and post-peak behaviour. Further research by Deam, Fragiacomo and Gross (2008) looked at a modified structural arrangement of the timber-concrete composite using straight and draped tendons to provide pre-stressing of the section which achieved a reduced mid-span deflection.

Semi-Prefabricated Timber-Concrete Composite

Yeoh et al (2008) reported on the semi-prefabricated timber-concrete composite floor system with cast in-situ concrete tipping that is currently being tested at the University of Canterbury. The following two figures, obtained from Yeoh et al (2008), show prefabricated timber “M” elements that are positioned into the building and then with 65 mm concrete topping cast in-situ. This system is currently being tested at University of Canterbury.

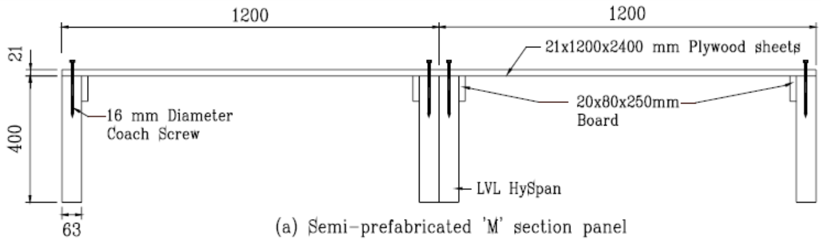


Figure 5.26 – Prefabricated Timber “M” Panels, UC Arrangement

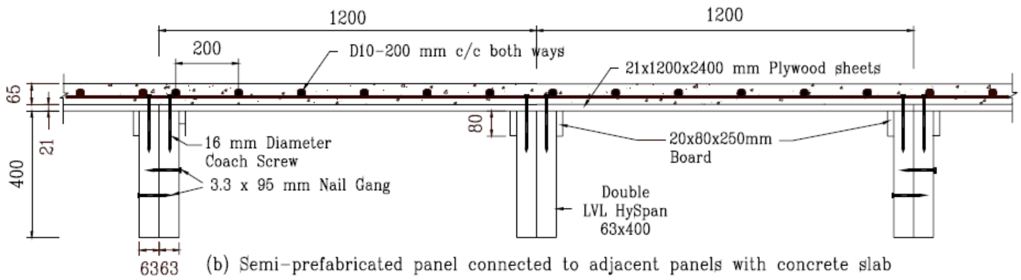


Figure 5.27 – TCC (Timber-Concrete Composite), UC Arrangement

The following figure was obtained from Yeoh et al (2008):

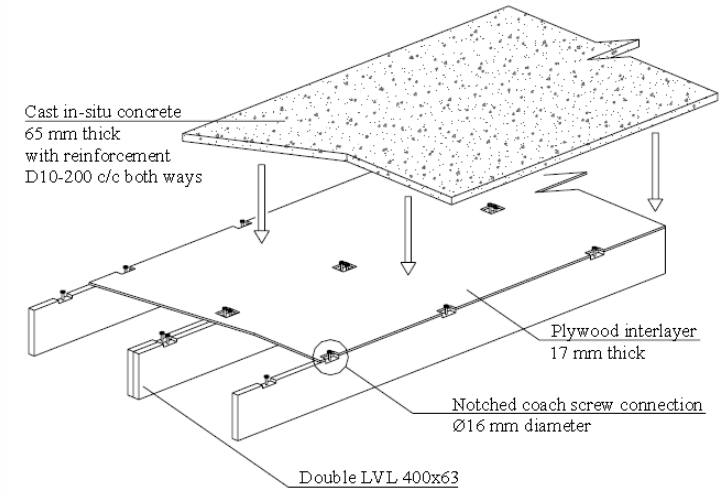


Figure 5.28 – Semi-Prefabricated TCC Floor System, UC Arrangement

Fully-Prefabricated Timber-Concrete Composite

A similar system has been investigated by Lukaszewska (2009) at Luleå University of Technology in Sweden. The aim of this system is to cast the concrete slab separately, dry connect to the timber members off site and transport as a unit to site. Lukaszewska, Fragiacomo and Johnsson (2010) also considered connecting the concrete slab and timber members on site.

The following figure and photo were obtained from Lukaszewska (2009):

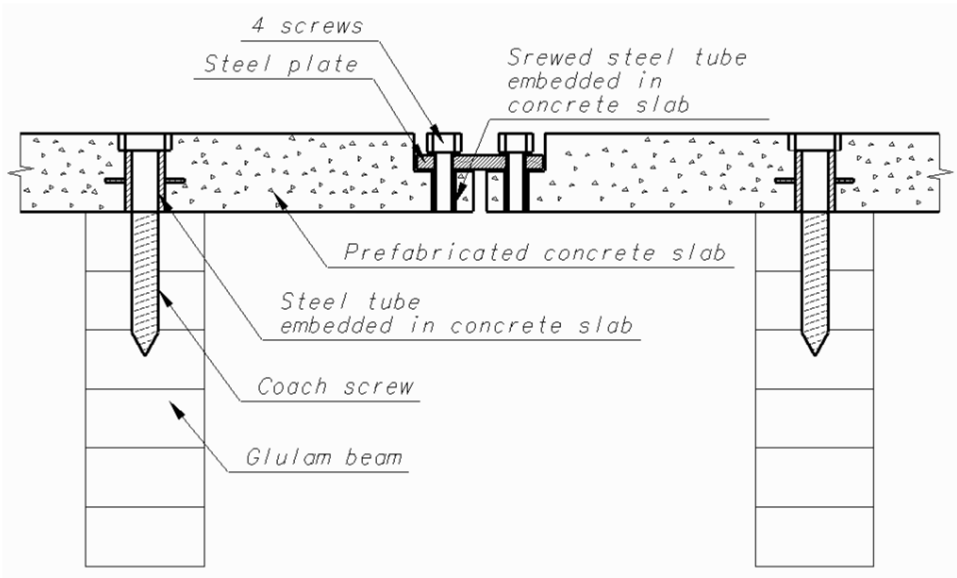


Figure 5.29 – Cross-Section of Fully Prefabricated TCC Floor System

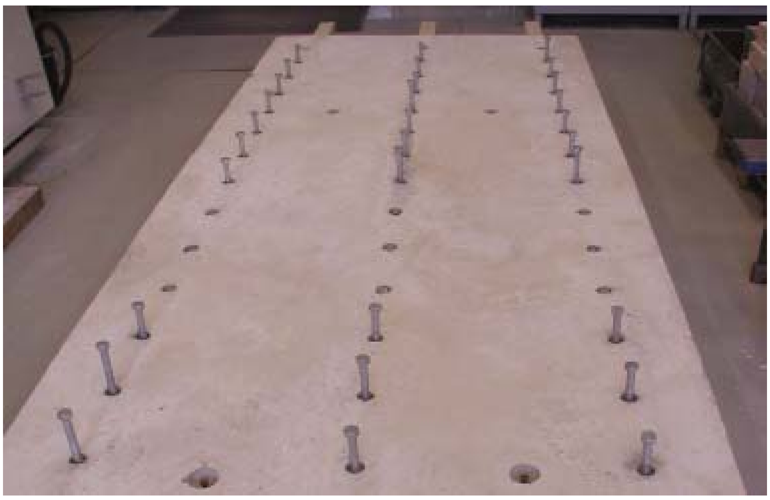


Figure 5.30 – Photo of Fully Prefabricated TCC Floor System

Finite Element Modelling

Finite element modelling of the long-term behaviour of timber-concrete composite beams is detailed in two companion reports, part 1 by Fragiacomo and Ceccotti (2006a) and part 2 by Fragiacomo (2006). The main findings were concrete creep, timber creep, mechano-sorptive creep of the connection and concrete shrinkage all contribute to the long-term deflection characteristics. Associated papers by Fragiacomo, Gutkowski, Balogh and Fast (2006), Fragiacomo, Gutkowski, Balogh and Fast (2007) and Gutkowski, Fast, Balogh and Fragiacomo (2006) have reported on the influence of notched shear key connection detail on the timber-concrete composite section.

The following graphic was obtained from Fragiacomo and Ceccotti (2006a):

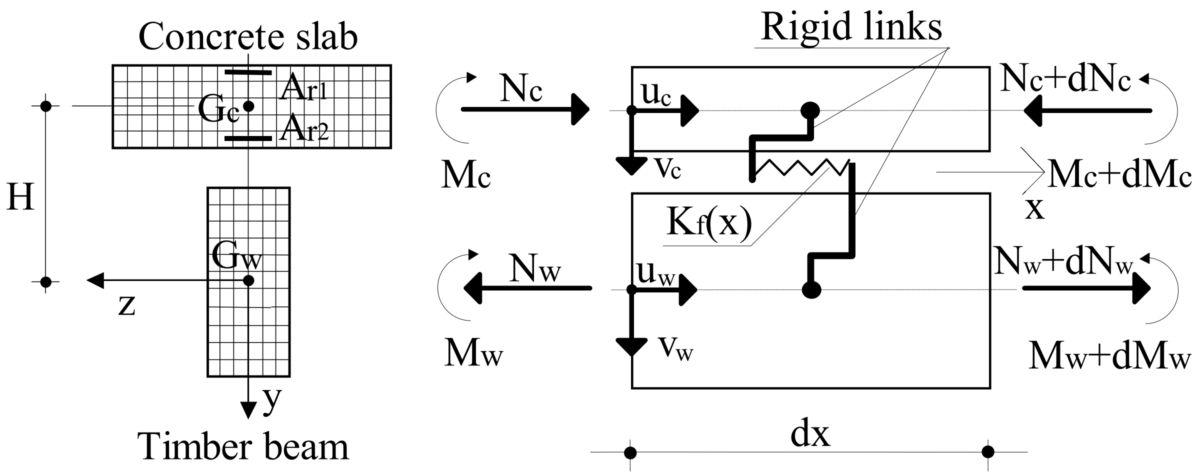


Figure 5.31 – Graphic of Finite Element Model

Following this investigation, an extension to the current *Eurocode 5 (*CEN, 2004a) design provisions for timber-concrete composite beams was proposed by Fragiacomo and Ceccotti (2006b) to take into account additional parameters: mechano-sorptive effect, concrete shrinkage, shrinkage/swelling of timber and concrete due to environmental variations, and propped construction effect. An additional approach was proposed by Schänzlin and Fragiacomo (2007) to separately evaluate internal forces and deflections from inelastic stains and vertical loads and then superimpose these.

Frangi, A., Knobloch, M., Fontana, M. (2010) have investigated the effect that temperature from fire has on screwed shear connection and found there is a resulting loss of strength and stiffness of the timber-concrete composite section. A simplified calculation model is described that show agreement with measurements from a full-scale fire test.

The following photo of TCC fire test was taken at BRANZ in 2009:

Figure 5.32 – Photo of TCC Fire Floor Test at BRANZ, UC Arrangement

5.5.2 Plywood Box Beam Joists

Plywood box beams (also known as plywood webbed beams) consist of solid timber flanges, plywood webs and solid timber stiffeners as shown in figure. APA (1998) provides a good reference for the structural design and fabrication of glued plywood-lumber beams. Span tables for plywood box beams for use in domestic housing have been prepared by FWPA (2008). The University of Technology, Sydney in Australia is investigating plywood box beams for use as floor joists.

The following graphic was obtained from FWPA (2008):

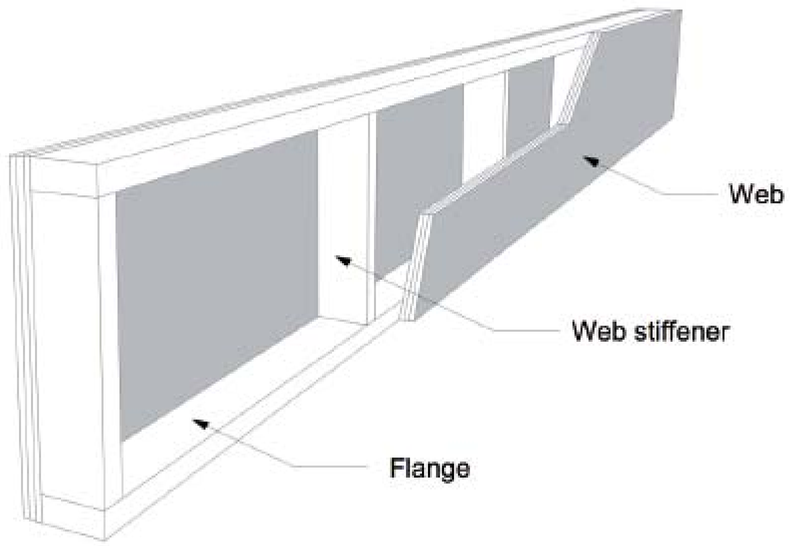


Figure 5.33 – Graphic of Plywood Box Beam with Cut-Away

5.5.3 Stressed-Skin Panel (SSP)

Stressed-skin panels (SSP) are preassembled from timber floor joists with glued timber flooring panel to the top for a one-sided stressed-skin panel, or with glued panels to top and bottom for a two-sided stressed-skin panel. These assemblies can be referred to as timber "I" or "T" stressed-skin floor panels. A variation of the one-sided stressed-skin panel is the timber-flange stressed-skin panel that has timber stiffener attached to the bottom of each floor joist.

APA (1996) provides a good reference for the structural design and fabrication of stressed-skin panels. The form of construction within this document largely relates to plywood skins and sawn timber stringers limiting the length to the availability of sawn timber, typically 6 m. Gerber and Crews (2009) have formulated design criteria to supplement the Australian timber structures design code (SA, 1997) based on extensive testing of these floors at the University of Technology in Sydney to achieve longer spans using LVL timber webs.

Bayne and Page (2009) have suggested the Australian timber manufacturing sector should develop and market cassette flooring to increase the use of added-value timber. Cassette flooring is a term used in the UK for prefabricated timber floor systems that are lifted into place on site to create an instant working platform, allowing speed of construction and safety. Typically floor joists contained within include sawn timber, timber "I" joists and parallel timber chord trusses.

The following graphics were obtained from APA (1996):

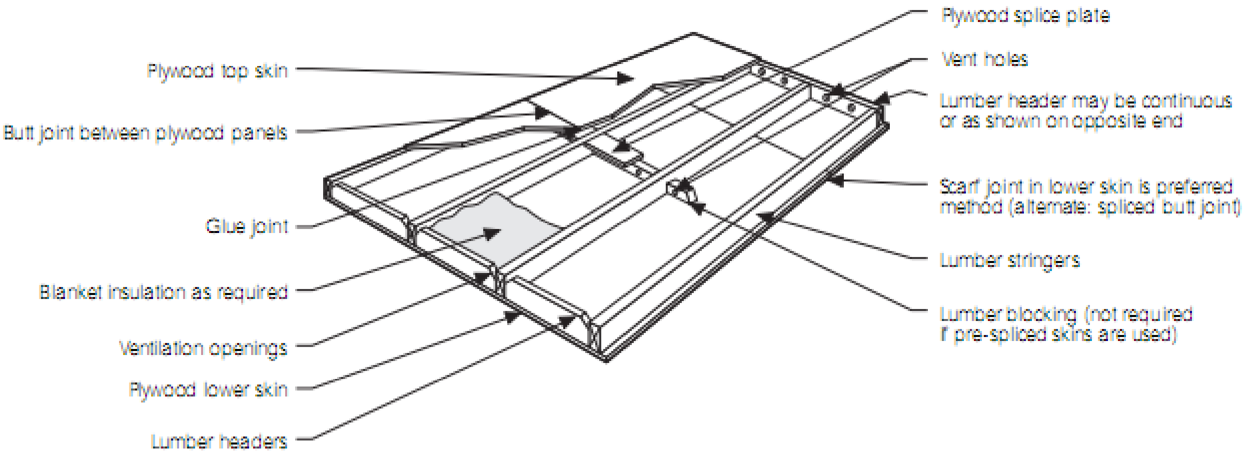


Figure 5.34 – Graphic of Typical Two-Sided SSP (Stressed-Skin Panel)

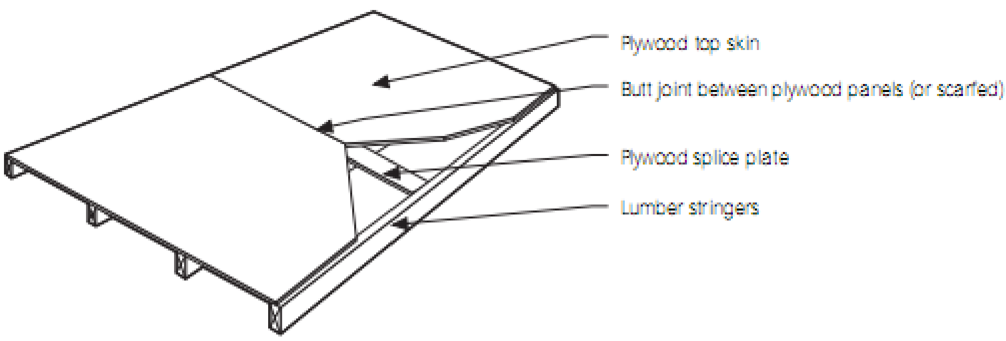


Figure 5.35 – Graphic of Typical One-Sided SSP

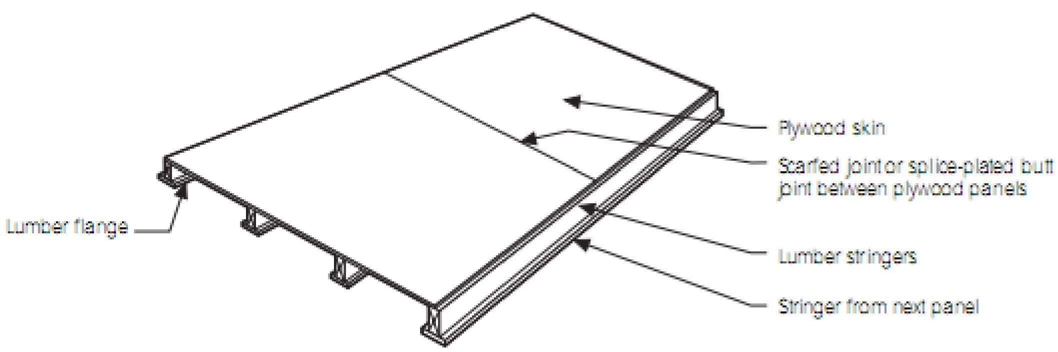


Figure 5.36 – Graphic of Typical Timber-Flange SSP

5.5.4 Cross-Laminated Timber (CLT)

Cross-laminated timber is a solid wood product that is fabricated by gluing full lengths of small dimension timber to form a single layer, with additional layers glued orthogonally to the previous, providing alternating bands of cross-directional strength. The panels typically comprise of three, five or seven layers that vary in thickness between 19 mm and 40 mm to provide various final section thicknesses. Frangi, Fontana, Hugi and Jübstl (2009) confirm that cross-laminated timber has become increasingly popular, particularly in Austria and Italy, for residential office, retail and industrial building types.

KLH Massivholz is an Austrian company that produces cross-laminated timber. KLH is short for kreuzlagenholz meaning cross-laminated timber and the direct translation of massivholz is solid wood. Their product is used for roof, wall and floor structural elements. KLH Massivholz produce a number of different panels up to maximum dimensions, length of 16.5 m, width of 2.95 m and depth of 500 mm. Included in their range is: a 7-layer product with alternating directions, a 7-layer product with double longitudinal layers on faces of panel and an 8-layer product with double longitudinal layers on faces and centre of panel.

König and Schmid (2007) investigated laminated deck plates comprising edgewise or flatwise laminations to determine whether 7 mm zero-strength layer beyond the char was applicable and recommend zero-strength layer of 9 mm for fire exposure on tension side and 13 mm for fire exposure on compression side.

Frangi, Fontana, Hugi and Jübstl (2009) note that the fire resistance of a structural cross-laminated timber, for example a floor in bending, the mechanical action is not linearly related to the charring as the number and direction of layers influence the structural characteristics. Their experiments on horizontal cross-laminated timber exposed to fire showed that behaviour of adhesive in the fire can lead to falling off of the char layer which results in earlier degradation of the subsequent layer.

The following photos were obtained from KLH Massivholz website (www.klh.at):

Figure 5.37 – Photo of CLT (Cross-Laminated Timber) Edge View

Figure 5.38 – Photo of CLT Floor during Construction

Figure 5.39 – Photo of CLT Completed Floor

5.5.5 Vertical Nailed Plank (VNP)

Vertical nailed plank (VNP) is another form of massive wood construction that comprises ordinary sawn timber planks orientated vertically and nailed together to form a large timber floor section (Natterer, Hamm and Favre, 1996). Massive wood construction offers advantages over traditional joist systems, with reduced structural depth and improved acoustic and thermal insulation (Natterer, 2002) and can be part of timber-concrete composite floor system.

The various soffit profiles shown in figure below break up the flat surface to assist with reflective noise within a room and they provide aesthetic interest. Additional details show possible acoustic treatment applied above to reduce airborne and impact noise through the floor section.

The following cross-sections were obtained from Sandoz (2004b):

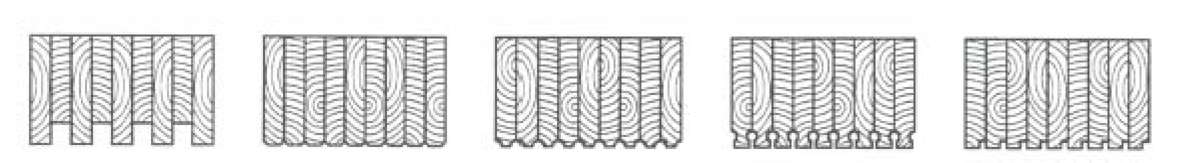


Figure 5.40 – Various Soffit Profiles of VNP (Vertical Nailed Plank) Floors

The following cross-sections were obtained from Natterer, Hamm and Favre (1996):

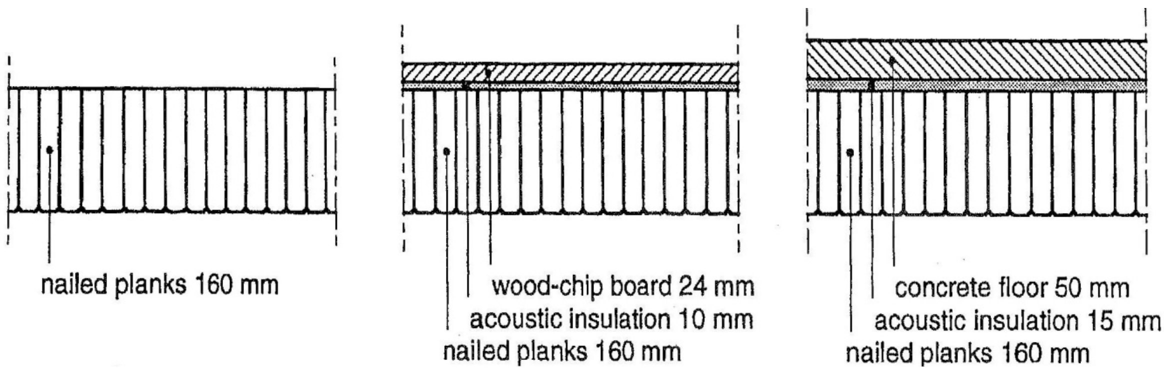


Figure 5.41 – VPN Floors with Various Cover Layers for Acoustic Insulation

5.5.6 Stress-Laminated Timber (SLT)

Stress-laminated timber is similar to vertical nailed plank (VNP) but instead of nailing each vertical laminate to the next, all of the laminates are held together with stressing stands across the full width of section at intervals along the length. This stress-laminated timber method provides increased load transfer. Although this assembly is mainly used for timber bridge structures, it could be considered for floor applications. Crews (2001) tested various stress-laminated timber assemblies for bridge applications. Flat plate configuration can span 9 m maximum, with built-up "T" and cellular configurations are required for longer spans.

The following cross-section was obtained from Timber Bridges in the United States website (www.tfhrc.gov):

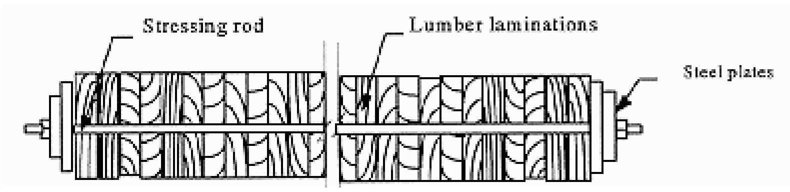


Figure 5.42 – Cross-Section of SLT (Stress-Laminated Timber) Flat Plate

The following cross-sections were obtained from Ritter et al (1995):

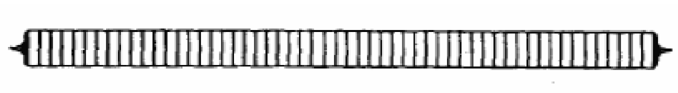


Figure 5.43 – Cross-Section of SLT Flat Plate

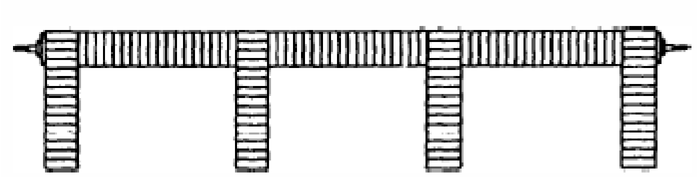


Figure 5.44 – Cross-Section of SLT "T" Beam

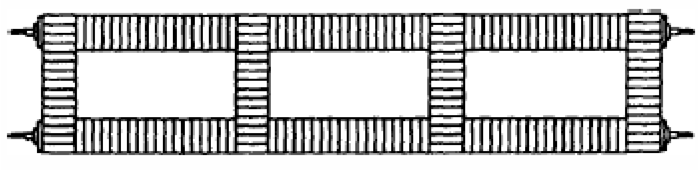


Figure 5.45 – Cross-Section of SLT Cellular Beam

5.5.7 Refond Floor

This innovative timber floor system was invented by Benny Refond from Sweden. Information regarding this system is not readily available suggesting it is currently not being marketed as a commercial product. Presently this floor is undergoing testing and study by Kirsi Salmela at Linnaeus University (formerly Växjö University, now combined with University of Kalmar).

The notes on photos (below) of this product indicate this system has two-way span properties, with the main span by truss action and the secondary span by inclined timber joists. It would appear that this secondary action would provide stiffness across this direction to control vibrations through the long span (Salmela, 2006).

The following photos were obtained from Salmela (2006):

Figure 5.46 – Photo of Refond Floor with Walls

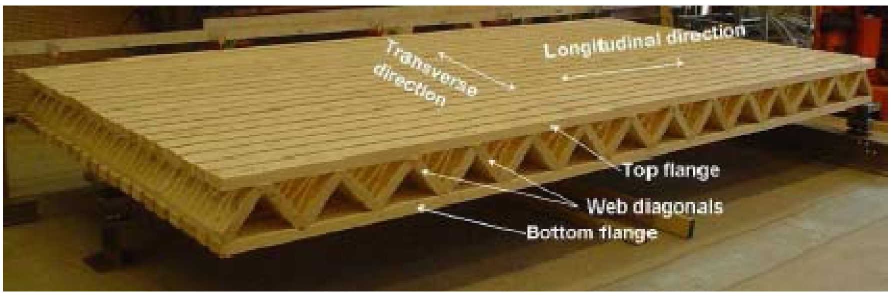


Figure 5.47 – Photo of Refond Floor at Linnaeus University

5.6 Non-Timber Floor Systems

This section outlines the range non-timber floor systems typically used in New Zealand and Australia. They all have concrete as the major component, which highlights concrete as the main competitor material to timber floor systems. Timber and timber-concrete composite floor systems will either compete with concrete floor systems or incorporate concrete as part of the floor system.

The non-timber floor systems are typically concrete with added concrete topping cast also, these include:

1. Flat Slab
2. Rib & Infill
3. Hollowcore
4. Double “T”
5. Steel Deck
6. Speedfloor
7. Hebel Supercrete Floor Panel

5.6.1 Flat Slab

Flat slab concrete floor system reinforced with steel pre-stressing strands, positioned on site, with 75 mm topping concrete cast in-situ. Maximum span is 8 m, with temporary propping required for the longer of these spans. The pre-stressing strands are positioned towards the bottom of the section to create a hogging moment that compensates for some of the sagging moment applied in service. Width dimension is 1200 mm, however 2400 mm units are also produced. Depth dimension ranges between 75 mm to 150 mm.

The following cross-section was obtained from Stahlton (2001):

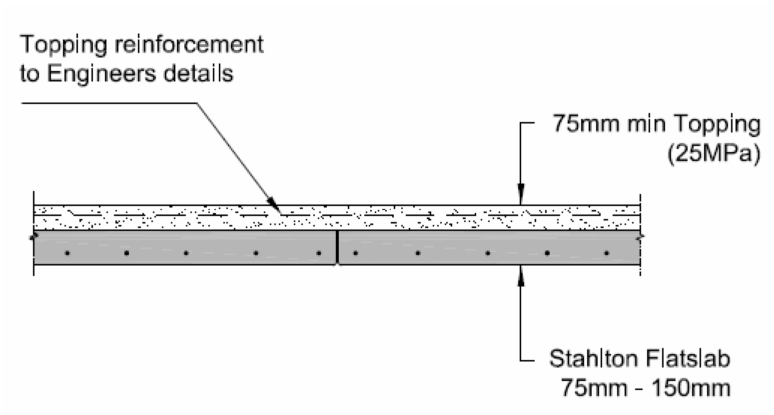


Figure 5.48 – Cross-Section of Concrete Flat Slab

5.6.2 Rib and Infill

Rib and infill concrete floor system are assembled on site, with 75 mm topping concrete cast in-situ. The ribs are concrete reinforced with steel pre-stressing strands, 150 mm width by 150 to 250 mm depth. The infill is generally 40 mm thick timber planks. Maximum span is 12 m, and temporary propping is normally required.

The following cross-section was obtained from Stresscrete (2009):

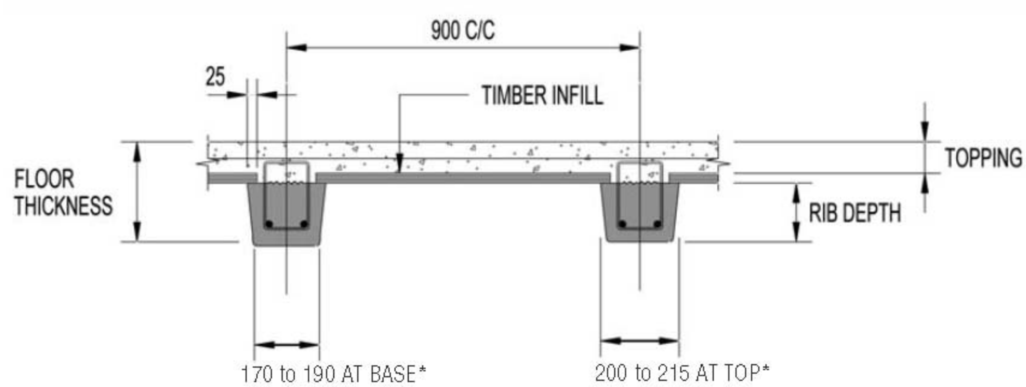


Figure 5.49 – Cross-Section Dimensions of Concrete Rib and Infill

5.6.3 Hollowcore

Hollowcore concrete floor system reinforced with steel pre-stressing strands, positioned on site, with 65 mm topping concrete cast in-situ. Maximum span is 18 m, and temporary propping is normally not required. Width dimension is 1200 mm. Depth dimension ranges between 150 mm to 400 mm.

The following cross-section was obtained from Stahlton (2001):

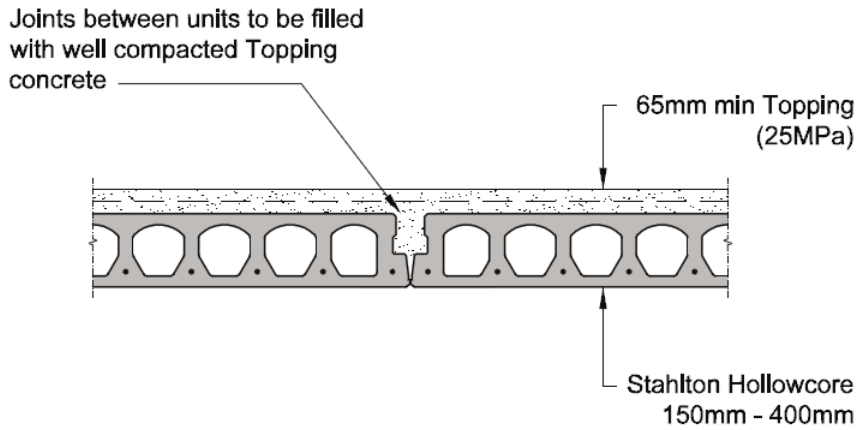


Figure 5.50 – Cross-Section of Hollowcore with Joint Detail

The following cross-section was obtained from Stresscrete (2009):

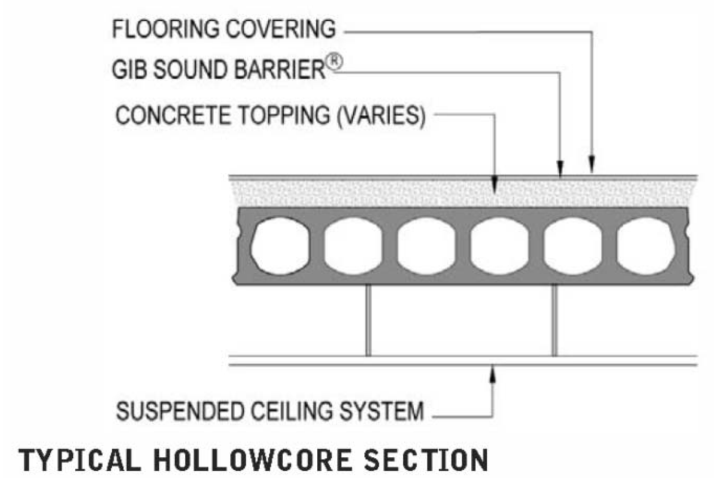


Figure 5.51 – Cross-Section of Hollowcore with Ceiling Detail

5.6.4 Double "T"

Double "T" concrete floor system reinforced with steel pre-stressing strands, positioned on site, with 50 mm topping concrete cast in-situ. Maximum span is 18 m, and temporary propping is normally not required for the larger units. Width dimension is 2400 mm. Depth dimension ranges between 200 mm to 550 mm.

The units are commonly web supported, however Stahlton designers have developed a system of flange support where, with additional end reinforcement and notched webs, the top flange supports the unit thereby eliminating the need for end formwork (Stahlton, 2001). Flange supported Double "T"s must be bedded on a sand-cement mortar. This must be evenly spread just prior to the unit being placed (Stresscrete, 2009).

The following cross-section was obtained from Stahlton (2001):

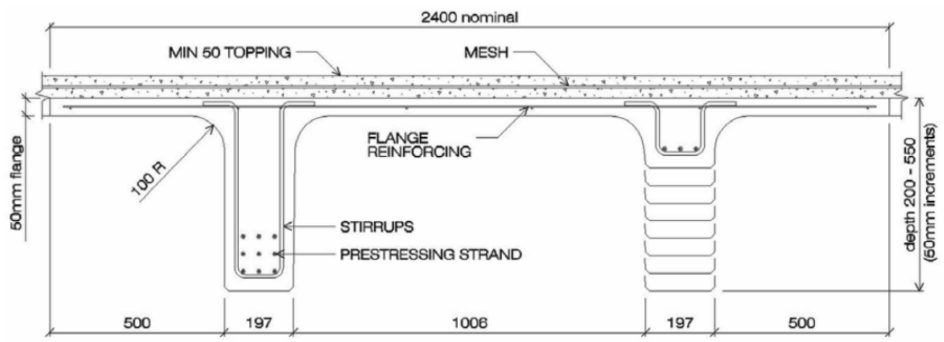


Figure 5.52 – Cross-Section Dimensions of Concrete Double "T"

5.6.5 Steel Deck

There are a variety of steel deck systems to support concrete cast in-situ. Most of these are trapezoidal trough profiles except for Flatdec, Uni-Floor and Tray-dec 300, which provide a flat soffit surface. They all typically require propping during construction to support wet concrete topping, except for ComFlor 210, which is a deep trough section that can span 5.4 m un-propped for normal weight concrete and 6.0 m for lightweight concrete. With two lines of propping, a maximum span of 8.7 m is achievable with ComFlor 210.

Corus:	ComFlor 60, ComFlor 80 and ComFlor 210
Dimond:	HiBond and Flatdec
Formsteel Industries:	Svelte-Floor and Uni-Floor
Tray-dec New Zealand Ltd:	Tray-dec 300, Concrete Saver 60 and Ultra-Span 80

The following cross-sections and photo were obtained from Dimond (2006):

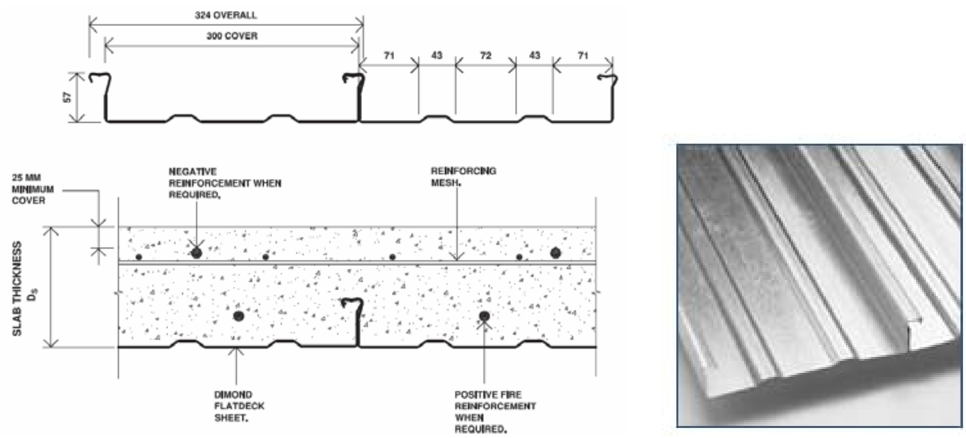


Figure 5.53 – Cross-Section and Photo of Dimond Flatdeck Steel Tray

The following cross-section and graphic were obtained from Corus NZ (2002):

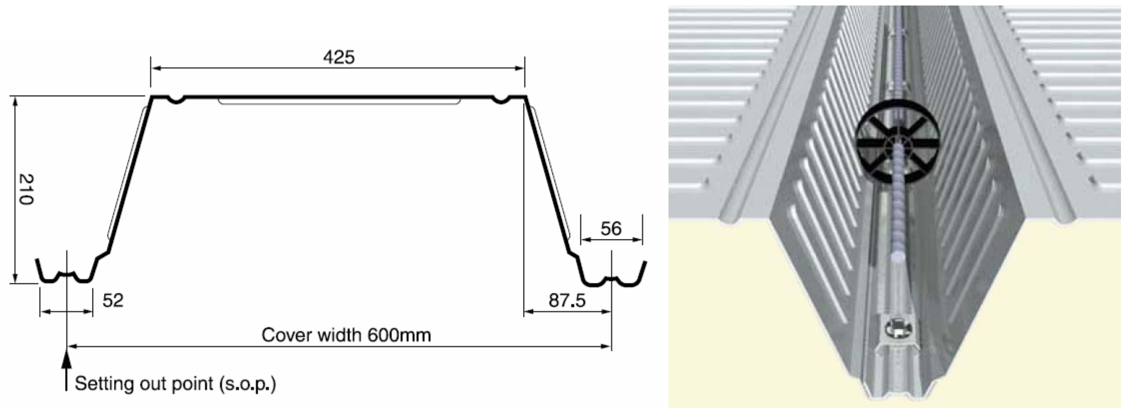


Figure 5.54 – Cross-Section and Graphic of Comflor 210 Steel Tray

5.6.6 Speedfloor

Speedfloor steel joist floor system with reinforced concrete slab cast in-situ incorporates temporary plywood formwork to support the wet concrete. The system has three options of joist centres 630 mm, 930 mm and 1230 mm. The concrete slab is either 75 or 90 mm. Maximum span for 400 mm deep joists at 630 mm centres with 75 mm topping is 10 m with temporary propping or 8 m without temporary propping.

The following cross-section and graphic were obtained from Speedfloor (2001):

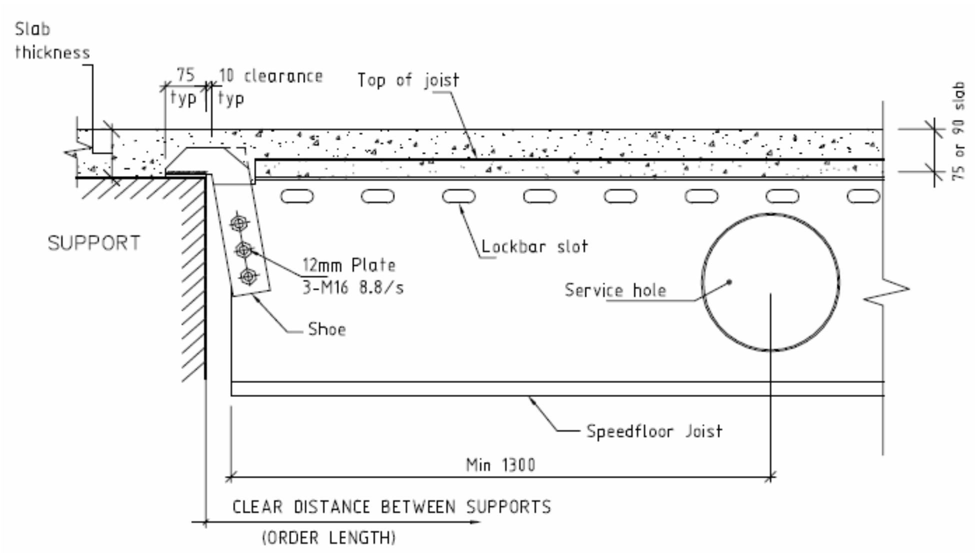


Figure 5.55 – Cross-Section of Speedfloor Steel Joist System

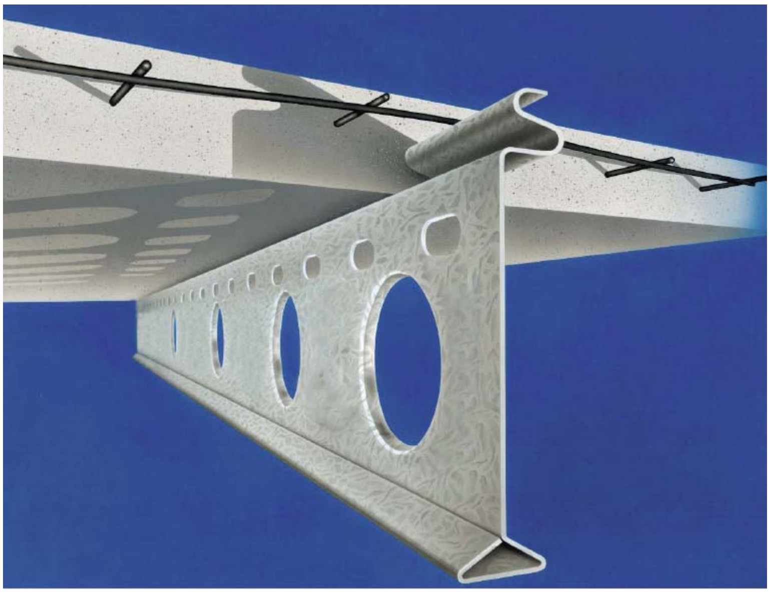


Figure 5.56 – Graphic of Speedfloor Steel Joist System

5.6.7 Hebel® Supercrete Floor Panel

Hebel is an aerated autoclaved concrete (AAC) product, with standard dry density range of 500 to 650kg/m³. The Hebel Supercrete structural floor is constructed with reinforced panels between 150 mm to 300 mm thick. Width dimension is 600 mm and maximum length is 6.0 m, which fixes the maximum clear span is less than 6.0 m for the 300 mm thick panel. Refer to CSR Hebel Technical Manual (Hebel Aus, 2006).

The following layout and photos were obtained from Hebel NZ (2009a):

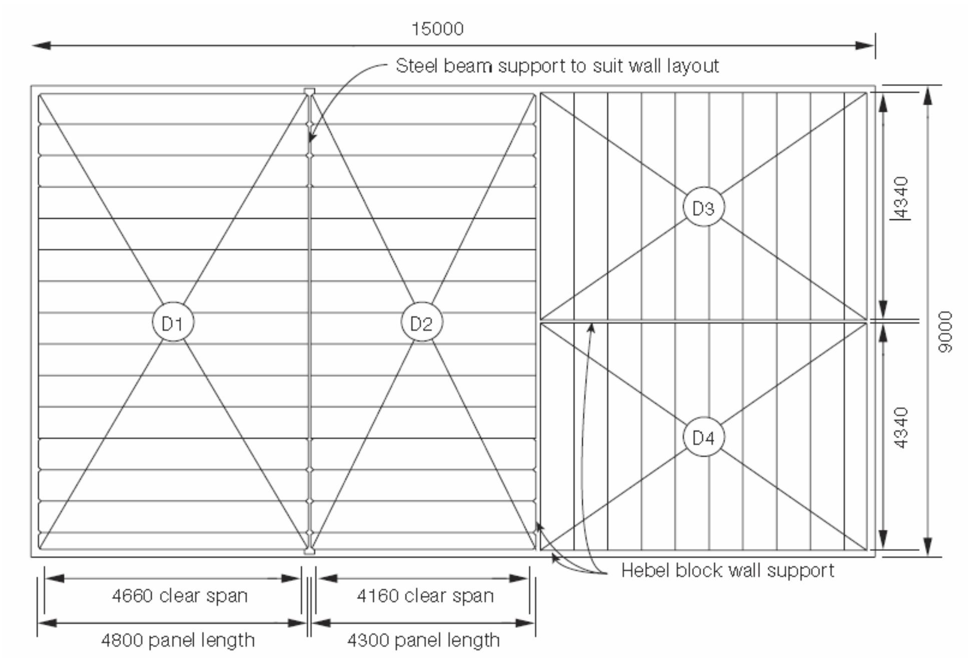


Figure 5.57 – Layout Arrangement of Hebel® Supercrete Flooring

Figure 5.58 – Photos of Hebel® Supercrete, Base-Floor and Mid-Floor

6. Structural Performance of Timber Floor Systems

This chapter details information on structural performance for the various timber floor systems identified.

6.1 Solid Timber Joists

Solid timber refers to sawn timber joists within limits of NZS 3604, laminated veneer lumber (LVL) and glue laminated timber (glulam).

1.1 Sawn Timber Joists
1.2 Glue Laminated (Glulam) Timber Joists
1.3 Laminated Veneer Lumber (LVL) Joists

6.1.1 Sawn Timber Joists

The following span capacity information was sourced from NZS 3604 (SNZ, 1999):

- 3.0 kPa floor live load
- 4.6 m simply supported 290 x 45 VSG8 joists at 400 mm centres

6.1.2 Glue Laminated (Glulam) Timber Joists

The following span capacity information was sourced from New Zealand Glulam Span Tables (NZPMA, 2008):

- 3.0 kPa floor live load
- 5.5 m simply supported 360 x 90 GL10 at 1200 mm centres
- 7.5 m simply supported 495 x 90 GL10 at 1200 mm centres
- 9.5 m simply supported 630 x 90 GL10 at 1200 mm centres

6.1.3 Laminated Veneer Lumber (LVL) Joists

6.1.3.1 Hyspan® LVL

The following span capacity information was sourced from Futurebuild Technical Note 84-06-03 (CHH, 2006):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 7.8 m simply supported 400 x 63 Carter Holt Harvey Hyspan at 400 mm centres

The following span capacity information was sourced from Design IT Software (CHH, 2009):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 9.7 m simply supported 600 x 63 Carter Holt Harvey Hyspan at 450 mm centres
- 9.9 m simply supported 600 x 63 Carter Holt Harvey Hyspan at 400 mm centres
- 10.4 m simply supported 600 x 63 Carter Holt Harvey Hyspan at 300 mm centres

6.1.3.2 NelsonPine® LVL

The following span capacity information was sourced from Design Guide and Span Tables (Nelson Pine, 2003a):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 8.9 m simply supported 610 x 63 NelsonPine LVL at 450 mm centres
- 9.9 m simply supported 610 x 63 NelsonPine LVL at 300 mm centres

The following span capacity information was sourced from NP Design NZ LVL 10 Software (Nelson Pine, 2003b):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 8.9 m simply supported 610 x 63 NelsonPine LVL at 450 mm centres
- 9.2 m simply supported 610 x 63 NelsonPine LVL at 400 mm centres
- 9.9 m simply supported 610 x 63 NelsonPine LVL at 300 mm centres

6.2 Timber "I" Joists

2.1 HyJOIST

2.2 LumberworX

2.3 Hyne

6.2.1 HyJOIST®

The following span capacity information was sourced from Futurebuild Technical Note 84-06-03 (CHH, 2006):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 6.8 m simply supported HJ400 90 Carter Holt Harvey HyJOIST at 400 mm centres

The following span capacity information was sourced from DesignIT Software (CHH, 2009):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 6.6 m simply supported HJ 400 90 Carter Holt Harvey HyJOIST at 450 mm centres
- 6.8 m simply supported HJ 400 90 Carter Holt Harvey HyJOIST at 400 mm centres
- 7.3 m simply supported HJ 400 90 Carter Holt Harvey HyJOIST at 300 mm centres

6.2.2 LumberworX®

The following span capacity information was sourced from "I" Beam Specifiers & Constructors Guide (LumberworX, 2009):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 5.8 m simply supported LIB 300 90 "I" Beam at 450 mm centres
- 6.0 m simply supported LIB 300 90 "I" Beam at 400 mm centres
- 6.5 m simply supported LIB 300 90 "I" Beam at 300 mm centres

6.2.3 Hyne®

The following span capacity information was sourced from Design-In-Hyne Software (Hyne, 2009):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 4.7 m simply supported IB 300 70 Hyne "I" Beam at 450 mm centres
- 5.0 m simply supported IB 300 70 Hyne "I" Beam at 400 mm centres
- 5.8 m simply supported IB 300 70 Hyne "I" Beam at 300 mm centres

The following span capacity information was sourced from Construction Guide (Hyne, 2006):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 4.7 m simply supported IB 300 70 Hyne "I" Beam at 450 mm centres
- 5.0 m simply supported IB 300 70 Hyne "I" Beam at 400 mm centres
- 5.8 m simply supported IB 300 70 Hyne "I" Beam at 300 mm centres

6.3 Parallel Timber Chord Trusses

3.1 Pryda Longreach

3.2 Pryda Span

3.3 Posi-STRUT

6.3.1 Pryda® Longreach

The following span capacity information was sourced from Pryda Floor and Rafter Truss Systems (Pryda, 2006):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 6.6 m simply supported FT 450/3 90 x 45 MSG12 trusses at 450 mm centres
- 7.2 m simply supported FT 450/3 90 x 45 MSG12 trusses at 400 mm centres
- 7.7 m simply supported FT 450/3 90 x 45 MSG12 trusses at 300 mm centres

6.3.2 Pryda® Span

The following span capacity information was sourced from Pryda Floor and Rafter Truss Systems (Pryda, 2006):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 6.3 m simply supported PS 410/3 90 x 45 MSG12 trusses at 450 mm centres
- 7.0 m simply supported PS 410/3 90 x 45 MSG12 trusses at 400 mm centres
- 7.5 m simply supported PS 410/3 90 x 45 MSG12 trusses at 300 mm centres

6.3.3 Posi-STRUT™

The following span capacity information was sourced from Gang-Nail Posi-STRUT Truss Systems (MiTek, 2008):

- 3.0 kPa floor live load, 40 kg/m² dead load
- 6.6 m simply supported PS 40 60 x 05 MSG10 at 450 mm centres
- 7.0 m simply supported PS 40 60 x 05 MSG10 at 400 mm centres

6.4 Recently Introduced Timber Floor Systems

4.1 Hebel 75 mm PowerFloor
4.2 Flexus Floor
4.3 TECbeam
4.4 TECslab
4.5 Potius
4.6 Lignatur
4.7 Wenus
4.8 O'Portune
4.9 D-Dalle
4.10 Structural Insulated Panel (SIP)

6.4.1 Hebel® 75 mm PowerFloor™ on Timber Joists

The following span capacity information was sourced from Timber Joists for Hebel Panel Flooring (Hebel NZ, 2009b):

- 3.0 kPa floor live load
- 3.6 m simply supported on 290 x 45 MSG8 at 360 mm centres, deflection limit L/250
- 3.3 m simply supported on 290 x 45 MSG8 at 360 mm centres, deflection limit L/600

6.4.2 Flexus Floor

The following span capacity information was sourced from Flexus Design Properties & Detailing (Reid, 2010):

- 3.0 kPa floor live load
- 6.6 m simply supported PS 410/3 90 x 45 MSG12 trusses at 450 mm centres

6.4.3 TECbeam®

The following span capacity information was sourced from Floor Joist Span Tables (TECbeam, 2009):

- 3.0 kPa floor live load
- 6.6 m simply supported 354 x 71 beams 600 mm centres
- 7.2 m simply supported 354 x 71 beams 450 mm centres
- 7.5 m simply supported 354 x 71 beams 400 mm centres
- 8.1 m simply supported 354 x 71 beams 300 mm centres

6.4.4 TECslab®

The following span capacity information was sourced from directly from TECbeam in-house design team:

- 3.0 kPa floor live load
- 6.0 m simply supported 354 x 71 beams 600 mm centres
- 6.6 m simply supported 354 x 71 beams 450 mm centres
- 6.8 m simply supported 354 x 71 beams 400 mm centres
- 7.5 m simply supported 354 x 71 beams 300 mm centres

6.4.5 Potius™

The following span capacity information was sourced from directly from TECbeam in-house Engineer, Gavin Robertson:

Without concrete

- 3.0 kPa floor live load
- 140 x 45 LVL “T” flange
- 400 x 36 LVL beams, two per 1.2 m wide floor unit
- 36 mm top skin
- Overall depth 481 mm
- 8.0 m simply supported

With non-composite 75 mm concrete topping

- 3.0 kPa floor live load
- 140 x 45 LVL “T” flange
- 400 x 36 LVL beams, two per 1.2 m wide floor unit
- 36 mm top skin
- Overall depth 556 mm
- 7.0 m simply supported

With composite 75 mm concrete topping

- 3.0 kPa floor live load
- 140 x 45 LVL “T” flange
- 400 x 36 LVL beams, two per 1.2 m wide floor unit
- 36 mm top skin
- Overall depth 556 mm
- 8.3 m simply supported

6.4.6 Lignatur®

The following span capacity information was sourced from Lignatur Workbook (Lignatur, 2009):

- 3.0 kPa floor live load
- 8.2 m simply supported on 320 mm deep element, deflection limit L/600
- 9.1 m simply supported on 320 mm deep element, deflection limit L/450
- 10.0 m simply supported on 320 mm deep element, deflection limit L/300

6.4.7 Wenus®

The following span capacity information was sourced from Wenus Technical Description (CBS-CBT, 2009c):

- 3.0 kPa floor live load, assumed
- 5 m approximately

6.4.8 O'Portune®

The following span capacity information was sourced from O'Portune Technical Description (CBS-CBT, 2009b):

- 3.0 kPa floor live load, assumed
- 12 m approximately

6.4.9 D-Dalle®

The following span capacity information was sourced from D-Dalle Technical Description (CBS-CBT, 2009a):

- 3.0 kPa floor live load, assumed
- 18 m approximately

6.4.10 Structural Insulated Panel (SIP)

The following span capacity information was sourced from Premier Building Systems Design Manual (PBS, 2009):

- 3.0 kPa floor live load
- 3.0 m simply supported for 286 mm, Panel Core Standard, deflection limit L/360
- 4.9 m simply supported for 286 mm, Panel Core Lumber, deflection limit L/360
- 5.4 m simply supported for 286 mm, Panel Core “I” Joist, deflection limit L/360

6.5 Under Development Timber Floor Systems

5.1 Timber-Concrete Composite (TCC)

5.2 Plywood Box Beam Joists

5.3 Stressed-Skin Panel (SSP)

5.4 Cross-Laminated Timber (CLT)

5.5 Vertical Nailed Plank (VPN)

5.5 Stress-Laminated Timber (SLT)

5.6 Refond Floor

6.5.1 Timber-Concrete Composite (TCC)

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 9.0 m, current testing at University of Canterbury
- 9.0 m, from Ramboll information

6.5.2 Plywood Box Beam Joists

Canadian Curve for Vibration Control

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 4.3 m estimated for 300 mm deep
- 5.1 m estimated for 400 mm deep
- 6.5 m estimated for 600 mm deep

2 mm for 1.0 kN for Vibration Control

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 5.0 m estimated for 300 mm deep, assumed similar to “I” beam
- 6.4 m estimated for 400 mm deep, assumed similar to “I” beam
- 8.0 m estimated for 600 mm deep

6.5.3 Stressed-Skin Panel (SSP)

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 7.5 m estimated for sawn timber webs
- 10.0 m estimated for LVL webs

6.5.4 Cross-Laminated Timber (CLT)

The following span capacity information was sourced from Engineering (KLH, 2008):

- 3.0 kPa floor live load
- 8.0 m for double span due to 16.0 m maximum product length
- 10.0 m approximately for 300 mm deep, deflection limit L/400

6.5.5 Vertical Nailed Plank (VNP)

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 9.0 m estimated for 290 mm deep VSG8, deflection limit L/400
- 10.0 m estimated for 300 mm deep LVL10, deflection limit L/400

6.5.6 Stress-Laminated Timber (SLT)

The following span capacity information has been estimated:

- 3.0 kPa floor live load
- 9.0 m estimated for 290 mm deep VSG8, deflection limit L/400
- 10.0 m estimated for 300 mm deep LVL10, deflection limit L/400

6.5.7 Refond Floor

The following span capacity information was sourced from Salmela (2006):

- 4.8 m, current testing at Linnaeus University, Sweden

7. Fire Performance of Timber Floor Systems

This chapter details information on fire performance for the various timber floor systems identified.

See **Appendix C** of this report for extracts from GIB Fire Rated Systems (Winstone Wallboards, 2006a), where data was sourced for Tables 7.1 to 7.10 inclusive.

7.1 Solid Timber Joists

1.1 Sawn Timber Joists

1.2 Glue Laminated (Glulam) Timber Joists

1.3 Laminated Veneer Lumber (LVL) Joists

7.1.1 Sawn Timber Joists

Floor joists must comply with NZS 3604 and be a minimum of 200 x 50 mm spaced at 600 mm maximum. Solid strutting is required at 1800 mm centres.

Note: Universal ceilings can be used with all systems but are not included in tables where more economical solutions are available.

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and is valid for solid timber joists within scope of NZS 3604 (SNZ, 1999):

Table 7.1 – GIB® Fire Rated Floor/Ceiling Systems for NZS 3604 Timber Joists

NZS 3604 TIMBER JOISTS – FIRE RATED FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBFC 15	LB	15/15/15	38	31	1 layer 10mm GIB Ultraline or 13mm GIB Standard	40
GBFC 45	LB	45/45/45	39	32	1 layer 13mm GIB Fyreline	44
GBFC 60	LB	60/60/60	39	32	1 layer 16mm GIB Fyreline	46
GBFC 90	LB	90/90/90	41	34	2 layers 16mm GIB Fyreline	63
NZS 3604 TIMBER JOISTS – FIRE RATED FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBSC 30	LB	30/30/30	48	43	USG ScrewFix Suspension system 1 layer 13mm GIB Fyreline	50
GBSC 60a	LB	60/60/60	53	43	USG ScrewFix Suspension system 2 layers 13mm GIB Fyreline	60
GBSC 60b	LB	60/60/60	50	43	USG Drywall Grid suspension system 1 layer of 16mm GIB Fyreline	54
GBSC 90	LB	90/90/90	53	43	USG Drywall Grid suspension system 1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline	64

Fire resistance using charring rates for sawn timber members is not applicable as minimum dimension is typically less than 90 mm, therefore protective gypsum linings are normally required.

7.1.2 Glue Laminated (Glulam) Timber Joists

Fire resistance for members with minimum 90 mm dimension can be derived using charring rates. GIB fire rated floor/ceiling systems may not be applicable for spans outside NZS 3604, therefore fire rated systems for LVL and glulam will need specific investigation, otherwise use Universal Ceilings from Winstone Wallboards (2006a).

Table 7.2 – GIB® Fire Rated Universal Ceilings for Timber or Steel Joists

TIMBER OR STEEL JOISTS – FIRE RATED CEILING SYSTEMS – UNIVERSAL CEILINGS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBUC 15	LB/NLB	15/15/15	–	–	1 layer 13mm GIB Fyreline	–
GBUC 30	LB/NLB	30/30/30	–	–	1 layer 16mm GIB Fyreline	–
GBUC 45	LB/NLB	45/45/45	–	–	2 layers 13mm GIB Fyreline	–
GBUC 60	LB/NLB	60/60/60	–	–	1 layer 16mm GIB Fyreline & 1 layer 13mm GIB Fyreline	–
GBUC 90	LB/NLB	90/90/90	–	–	2 layers 19mm GIB Fyreline	–

Fire protection is not required for many glulam floor systems. Calculation methods utilising charring rates for minimum 90 mm least dimension members can be found in the following documents:

- Timber Design Guide (Buchanan, 2007)
- Structural Design for Fire Safety (Buchanan, 2001)
- Design of Timber Structures, Structural Fire Design, Part 1-2, Eurocode 5 (CEN, 2004b)

7.1.3 Laminated Veneer Lumber (LVL) Joists

7.1.3.1 Hyspan® LVL

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and is valid for Hyspan LVL joists (and HyJOIST timber "I" joists):

Table 7.3 – GIB® Fire Rated Floor/Ceiling Systems for Hyspan or Hyjoist

HYSPAN OR HYJOIST – FIRE RATED FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBFC 15	LB	15/15/15	38	31	1 layer 10mm GIB Ultraline or 13mm GIB Standard	40
GBCJ 45	LB	45/45/45	39	32	1 layer 13mm GIB Fyreline	40
GBCJ 60	LB	60/60/60	39	32	1 layer 16mm GIB Fyreline	44

7.1.3.2 NelsonPine® LVL

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a):

Table 7.4 – GIB® Fire Rated Universal Ceilings for Timber or Steel Joists

TIMBER OR STEEL JOISTS – FIRE RATED CEILING SYSTEMS – UNIVERSAL CEILINGS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBUC 15	LB/NLB	15/15/15	–	–	1 layer 13mm GIB Fyreline	–
GBUC 30	LB/NLB	30/30/30	–	–	1 layer 16mm GIB Fyreline	–
GBUC 45	LB/NLB	45/45/45	–	–	2 layers 13mm GIB Fyreline	–
GBUC 60	LB/NLB	60/60/60	–	–	1 layer 16mm GIB Fyreline & 1 layer 13mm GIB Fyreline	–
GBUC 90	LB/NLB	90/90/90	–	–	2 layers 19mm GIB Fyreline	–

LVL floor members with can be designed with minimum 90 mm least dimension can be designed in the same way as glulam floor systems. Calculation methods utilising charring rates for minimum 90 mm least dimension members can be found in the following documents:

- Timber Design Guide (Buchanan, 2007)
- Structural Design for Fire Safety (Buchanan, 2001)
- Design of Timber Structures, Structural Fire Design, Part 1-2, Eurocode 5 (CEN, 2004b)

7.2 Timber "I" Joists

2.1 HyJOIST

2.2 LumberworX

2.3 Hyne

7.2.1 HyJOIST®

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and is valid for HyJOIST timber "I" joists (and Hyspan LVL joists):

Table 7.5 – GIB® Fire Rated Floor/Ceiling Systems for Hyspan or Hyjoist

HYSPAN OR HYJOIST – FIRE RATED FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBFC 15	LB	15/15/15	38	31	1 layer 10mm GIB Ultraline or 13mm GIB Standard	40
GBCJ 45	LB	45/45/45	39	32	1 layer 13mm GIB Fyreline	40
GBCJ 60	LB	60/60/60	39	32	1 layer 16mm GIB Fyreline	44

7.2.2 LumberworX®

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and is valid for proprietary "I" joists:

Table 7.6 – GIB® Fire Rated Floor/Ceiling Systems for Proprietary "I" Joist System

PROPRETARY "I" JOIST SYSTEM – FIRE RATED FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBSC 30	LB	30/30/30	48	43	USG ScrewFix™ Suspension system 1 layer 13mm GIB Fyreline	50
GBSC 60a	LB	60/60/60	53	43	USG ScrewFix™ Suspension system 2 layers 13mm GIB Fyreline	60
GBSC 60b	LB	60/60/60	50	43	USG Drywall Grid suspension system 1 layer 16mm GIB Fyreline	54
GBSC 90	LB	90/90/90	53	43	USG Drywall Grid suspension system 1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline	64

7.2.3 Hyne®

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and is valid for proprietary "I" joists:

Table 7.7 – GIB® Fire Rated Floor/Ceiling Systems for Proprietary "I" Joist System

PROPRIETARY "I" JOIST SYSTEM – FIRE RATED FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBSC 30	LB	30/30/30	48	43	USG ScrewFix™ Suspension system 1 layer 13mm GIB Fyreline	50
GBSC 60a	LB	60/60/60	53	43	USG ScrewFix™ Suspension system 2 layers 13mm GIB Fyreline	60
GBSC 60b	LB	60/60/60	50	43	USG Drywall Grid suspension system 1 layer 16mm GIB Fyreline	54
GBSC 90	LB	90/90/90	53	43	USG Drywall Grid suspension system 1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline	64

Fire protection is required as these joist members have thin timber plywood or oriented strand board webs, which would burn through quickly if exposed to fire. Also, charring rates are not applicable for the timber flanges as these typically have a 45 mm least dimension.

7.3 Parallel Timber Chord Trusses

3.1 Pryda Longreach

3.2 Pryda Span

3.3 Posi-STRUT

7.3.1 Pryda® Longreach

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a):

Table 7.8 – GIB® Fire Rated Universal Ceilings for Timber or Steel Joists

TIMBER OR STEEL JOISTS – FIRE RATED CEILING SYSTEMS – UNIVERSAL CEILINGS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBUC 15	LB/NLB	15/15/15	–	–	1 layer 13mm GIB Fyreline	–
GBUC 30	LB/NLB	30/30/30	–	–	1 layer 16mm GIB Fyreline	–
GBUC 45	LB/NLB	45/45/45	–	–	2 layers 13mm GIB Fyreline	–
GBUC 60	LB/NLB	60/60/60	–	–	1 layer 16mm GIB Fyreline & 1 layer 13mm GIB Fyreline	–
GBUC 90	LB/NLB	90/90/90	–	–	2 layers 19mm GIB Fyreline	–

7.3.2 Pryda® Span

The following fire rating information was sourced from GIB Fire Rated Systems (Winstone Wallboards, 2006a):

Table 7.9 – GIB® Fire Rated Universal Ceilings for Timber or Steel Joists

TIMBER OR STEEL JOISTS – FIRE RATED CEILING SYSTEMS – UNIVERSAL CEILINGS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBUC 15	LB/NLB	15/15/15	–	–	1 layer 13mm GIB Fyreline	–
GBUC 30	LB/NLB	30/30/30	–	–	1 layer 16mm GIB Fyreline	–
GBUC 45	LB/NLB	45/45/45	–	–	2 layers 13mm GIB Fyreline	–
GBUC 60	LB/NLB	60/60/60	–	–	1 layer 16mm GIB Fyreline & 1 layer 13mm GIB Fyreline	–
GBUC 90	LB/NLB	90/90/90	–	–	2 layers 19mm GIB Fyreline	–

7.3.3 Posi-STRUT™

The following fire rating information was sourced from Gangnail Posi-STRUT Truss Systems (MiTek, 2008):

There are two systems for fire rating Posi-STRUT floor truss systems:

1. The GBPS series specific to Posi-STRUT. The GIB Fyreline is fixed to a 600 mm grid of ceiling strapping and nogging.
2. The GBUC system. The GIB Fyreline fixed directly to the underside of the Posi-STRUT trusses.

Table 7.10 – GIB® Fire Rated Floor/Ceiling Systems for Posi-Strut Joists

POSI-STRUT – FIRE RATED FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBPS 30	LB	30/30/30	–	–	1 layer 13mm GIB Fyreline	–
GBPS 60	LB	60/60/60	–	–	1 layer 16mm GIB Fyreline	–
GBPS 90	LB	SD	–	–	2 layers 16mm GIB Fyreline	–
POSI-STRUT – FIRE RATED CEILING SYSTEMS – UNIVERSAL CEILINGS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME	APPROX WEIGHT OF SYSTEM (kg/m²)
GBUC 30	LB/NLB	30/30/30	–	–	1 layer 16mm GIB Fyreline	–
GBUC 60	LB/NLB	SD	–	–	1 layer 16mm GIB Fyreline & 1 layer 13mm GIB Fyreline	–
GBUC 90	LB/NLB	SD	–	–	2 layers 19mm GIB Fyreline	–

- Note: **SD** denotes Specific Design, contact MiTek Design Office.

Fire protection is required as these joist members have thin metal plate connectors, which would rapidly fail if exposed to fire temperatures. Also, charring rates are not applicable for the top and bottom timber chords as these typically have a 45 mm least dimension.

7.4 Recently Introduced Timber Floor Systems

4.1 Hebel 75 mm PowerFloor

4.2 Flexus Floor

4.3 TECbeam

4.4 TECslab

4.5 Potius

4.6 Lignatur

4.7 Wenus

4.8 O'Portune

4.9 D-Dalle

4.10 Structural Insulated Panel (SIP)

7.4.1 Hebel® 75 mm PowerFloor™ on Timber Joists

The following fire rating information was sourced from Supercrete Panel Flooring (Hebel NZ, 2006):

- 75 mm Hebel PowerFloor
- Timber joists
- 230 mm minimum cavity
- R1.5 fibreglass batts
- Rondo furring channel on resilient mounts on alternate joists
- 1 layer 13mm Gyprock Fyrcheck plasterboard, plus
- 1 layer 16mm Gyprock Fyrcheck plasterboard
- FRL/FRR is 60/60/60

7.4.2 Flexus Floor

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.4.3 TECbeam®

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.4.4 TECslab®

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.4.5 Potius™

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)
- FRR 30/30/30 for NMIT sprinklered building

7.4.6 Lignatur®

The following fire rating information was sourced from Lignatur Workbook (Lignatur, 2009):

- REI 30 and REI 60 systems available for Lignatur box elements
- REI 30, REI 60 and REI 90 systems available for Lignatur shell elements
- REI 30, REI 60 and REI 90 systems available for Lignatur shell acoustic elements

7.4.7 Wenus®

The following fire rating information was sourced from Wenus Technical Description (CBS-CBT, 2009c):

- 30 minute fire resistance for 35 mm thick boards
- 60 minute fire resistance for 55 mm thick boards

7.4.8 O'Portune®

- The following fire rating information was sourced from O'Portune Technical Description (CBS-CBT, 2009b):

- 60 minute fire resistance for 60 mm thick boards
- 90 minute fire resistance by specific design
- 120 minute fire resistance by specific design

7.4.9 D-Dalle®

The following fire rating information was sourced from D-Dalle Technical Description (CBS-CBT, 2009a):

- 90 minute fire resistance for 60 mm thick boards

7.4.10 Structural Insulated Panel (SIP)

- Fire-resistant foams such as polyisocyanurate (PIR) can be used although increased cost
- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5 Under Development Timber Floor Systems

5.1 Timber-Concrete Composite (TCC)
5.2 Plywood Box Beam Joists
5.3 Stressed-Skin Panel (SSP)
5.4 Cross-Laminated Timber (CLT)
5.5 Vertical Nailed Plank (VPN)
5.5 Stress-Laminated Timber (SLT)
5.6 Refond Floor

7.5.1 Timber-Concrete Composite (TCC)

The following information was sourced from O'Neill (2009), is the fire resistance obtained for timber-concrete composite floor units without added fire protection, calculated using charring of timber joist members:

- 30 minute structural fire resistance
- 60 minute structural fire resistance
- 90 minute structural fire resistance
- 120 minute structural fire resistance

7.5.2 Plywood Box Beam Joists

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5.3 Stressed-Skin Panel (SSP)

- Information unavailable – not tested as yet
- Calculate using charring rates for 90 mm least dimension timber members
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5.4 Cross-Laminated Timber (CLT)

- Information unavailable – not tested as yet
- Calculate using charring rates for 90 mm least dimension timber members, refer also to Frangi, Knobloch and Fontana (2009)
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5.5 Vertical Nailed Plank (VNP)

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5.6 Stress-Laminated Timber (SLT)

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

7.5.7 Refond Floor

- Information unavailable – not tested as yet
- Consider using GIB Fire Rated Systems (Winstone Wallboards, 2006a)

8. Acoustic Performance of Timber Floor Systems

This chapter details information on acoustic performance for the various timber floor systems identified.

See **Appendix D** of this report for extracts from GIB Noise Control Systems (Winstone Wallboards, 2006b), where data was sourced for Tables 8.1 to 8.10 inclusive.

8.1 Solid Timber Joists

1.1 Sawn Timber Joists

1.2 Glue Laminated (Glulam) Timber Joists

1.3 Laminated Veneer Lumber (LVL) Joists

8.1.1 Sawn Timber Joists

Timber Joists to NZS 3604

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.1 – GIB® Noise Control Floor/Ceiling Systems for NZS 3604 Timber Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.1.2 Glue Laminated (Glulam) Timber Joists

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.2 – GIB® Noise Control Floor/Ceiling Systems for Glulam Timber Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.1.3 Laminated Veneer Lumber (LVL) Joists

8.1.3.1 Hyspan® LVL

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.3 – GIB® Noise Control Floor/Ceiling Systems for LVL Timber Joists

HYSPAN OR HYJOIST – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
HYSPAN OR HYJOIST – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.1.3.2 NelsonPine® LVL

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.4 – GIB® Noise Control Floor/Ceiling Systems for LVL Timber Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.2 Timber "I" Joists

2.1 HyJOIST

2.2 LumberworX

2.3 Hyne

8.2.1 HyJOIST®

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.5 – GIB® Noise Control Floor/Ceiling Systems for Timber "I" Joists

HYSPAN OR HYJOIST – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
HYSPAN OR HYJOIST – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.2.2 LumberworX®

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.6 – GIB® Noise Control Floor/Ceiling Systems for Timber "I" Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.2.3 Hyne®

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.7 – GIB® Noise Control Floor/Ceiling Systems for Timber "I" Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.3 *Parallel Timber Chord Trusses*

3.1 Pryda Longreach

3.2 Pryda Span

3.3 Posi-STRUT

8.3.1 Pryda® Longreach

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.8 – GIB® Noise Control Floor/Ceiling Systems for Timber Chord Truss Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.3.2 Pryda® Span

The following acoustic rating information was sourced from GIB Noise Control Systems (Winstone Wallboards, 2006b):

Table 8.9 – GIB® Noise Control Floor/Ceiling Systems for Timber Chord Truss Joists

NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 30a	LB	30/30/30	52	–	71*	2 layers 13mm GIB Standard
GBDFA 30d	LB	30/30/30	51	–	68*	1 layer 13mm GIB Noiseline
GBDFA 60c	LB	60/60/60	56	46	72*	2 layers 13mm GIB Fyreline
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
NZS 3604 TIMBER JOISTS – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

8.3.3 Posi-STRUT™

The following acoustic rating information was sourced from Gangnail Posi-STRUT Truss Systems (MiTek, 2008):

There are two systems for acoustic rating Posi-STRUT floor truss systems:

1) The GBDFA system uses a "direct fix clip", screwed onto the Posi-STRUT at 1200 mm maximum centres. This supports the furring channels.
2) The GBSCA system uses a suspended ceiling system.

Table 8.10 – GIB® Noise Control Floor/Ceiling Systems for Posi-Strut Joists

POSI-STRUT – NOISE CONTROL FLOOR/CEILING SYSTEMS						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBDFA 60b	LB	60/60/60	55	46	72*	2 layers 13mm GIB Fyreline
POSI-STRUT – NOISE CONTROL FLOOR/CEILING SYSTEMS – SUSPENDED GRID						
SPECIFICATION REFERENCE	LOAD BEARING CAPABILITY	FRR	STC	IIC BARE	IIC CARPET	LINING REQUIREMENTS TO UDERSIDE OF SUPPORT FRAME
GBSCA 30	LB	30/30/30	57	46	72*	2 layers 13mm GIB Fyreline
GBSCA 60a	LB	60/60/60	58	46	72*	1 layer 13mm GIB Fyreline & 1 layer 16mm GIB Fyreline

* IIC ratings with asterisk – the above IIC performance is achieved with a 48 oz hard twist wool hessian backed carpet over a rubber waffle underlay.

The acoustic ratings are based on testing performed by Winstone Wallboards Ltd and an opinion provided by Marshall Day Associates (96114RQ) for inter-tenancy floors (MiTek, 2008).

8.4 Recently Introduced Timber Floor Systems

4.1 Hebel 75 mm PowerFloor

4.2 Flexus Floor

4.3 TECbeam

4.4 TECslab

4.5 Potius

4.6 Lignatur

4.7 Wenus

4.8 O'Portune

4.9 D-Dalle

4.10 Structural Insulated Panel (SIP)

8.4.1 Hebel® 75 mm PowerFloor™ on Timber Joists

The following acoustic rating information was sourced from Supercrete Panel Flooring (Hebel NZ, 2006):

- 75 mm Hebel PowerFloor
- 230 mm minimum cavity
- R1.5 fibreglass batts
- Rondo furring channel on resilient mounts on alternate joists layer 13mm Standard plasterboard
- STC 54, IIC 28 – 8 mm ceramic tile with flexible adhesive on waterproof membrane
- STC 56, IIC 33 – 8 mm ceramic tile with flexible adhesive on concrete topping
- STC 58, IIC 40 – vinyl sheet floor covering on 6.8 mm sheet underlay
- STC 55, IIC 44 – 19mm T & G hardwood flooring on 75 x 30 mm timber battens
- STC 55, IIC 72 – carpet on medium duty underlay
- FRL/FRR is NIL
- 75 mm Hebel PowerFloor
- Timber joists
- 230 mm minimum cavity
- R1.5 fibreglass batts
- Rondo furring channel on resilient mounts on alternate joists
- 1 layer 13mm Gyprock Fyrcheck plasterboard, plus
- 1 layer 16mm Gyprock Fyrcheck plasterboard
- STC 57, IIC 31 – 8 mm ceramic tile with flexible adhesive on waterproof membrane
- STC 59, IIC 36 – 8 mm ceramic tile with flexible adhesive on concrete topping
- STC 60, IIC 42 – vinyl sheet floor covering on 6.8 mm sheet underlay
- STC 58, IIC 47 – 19mm T & G hardwood flooring on 75 x 30 mm timber battens
- STC 58, IIC 75 – carpet on medium duty underlay
- FRL/FRR is 60/60/60

8.4.2 Flexus Floor

The following acoustic rating information was sourced direct from Reid (Flexus manufacturer):

- 30 mm EEC floor
- Pryda Span PS 410 MSG12 at 450 mm centres
- Pink Batts Midfloor Silencer
- Stud and track ST001 acoustic resilient mount
- Rondo Type 129 steel ceiling battens at 600 centres
- 13mm GIB Braceline/Noiseline
- STC 57, IIC 35 – Bare floor
- STC ---, IIC 47 – 8 mm ceramic tile with flexible adhesive
- STC ---, IIC 51 – Floating timber floor
- STC ---, IIC 81 – Loop pile carpet on underlay
- FRL/FRR is NIL

8.4.3 TECbeam®

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.4.4 TECslab®

The following acoustic rating information was sourced from brochure (TECbeam, 2009):

- 75 mm CSR Hebel SoundFloor
- 1 layer Standard plasterboard
- R_W 54 to 56
- 75 mm CSR Hebel SoundFloor
- 2 to 3 layers Fyrecheck plasterboard
- R_W 58 to 62

8.4.5 Potius™

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.4.6 Lignatur®

Frangi, Knobloch and Fontana (2009) advise two different charging phases for hollowcore timber elements. The bottom timber layer is subject to one-dimensional charring while the vertical timber members receive increased two-dimensional heat flux in the insulating material. The sides of vertical timber members are protected with rock fibre batts with melt point greater than 1000°C to remain in place after bottom timber layer has burnt through. Frangi, Fontana and Schleifer report on bottom timber layer with perforation for reflective acoustics are greatly affected by fire due to increased surface are exposed to fire and penetration of heat into the holes.

The following acoustic rating information was sourced from Lignatur Workbook (Lignatur, 2009):

- Lignatur **box** element, **no** acoustic filling
- R_W 49, $L_{n,w}$ 67
- R_W 53, $L_{n,w}$ 62
- R_W 61, $L_{n,w}$ 59
- Lignatur **box** element, **maximum** acoustic filling
- R_W 61, $L_{n,w}$ 52
- R_W 68, $L_{n,w}$ 49
- R_W 69, $L_{n,w}$ 51
- Lignatur **shell** element, **no** acoustic filling
- R_W 59, $L_{n,w}$ 66
- R_W 59, $L_{n,w}$ 56
- Lignatur **shell** element, **maximum** acoustic filling
- R_W 72, $L_{n,w}$ 57
- R_W 72, $L_{n,w}$ 42

8.4.7 Wenus®

Sandoz and Leistner (2006) give a general comparison of sound performance properties for various timber floor systems, including vertical nailed plank, timber-concrete composite, O'Portune and D-Dalle. For acoustic improvement using added mass, the elements can be partially loaded with sand (CBS-CBT, 2009c).

8.4.8 O'Portune®

Sandoz and Leistner (2006) give a general comparison of sound performance properties for various timber floor systems, including vertical nailed plank, timber-concrete composite, O'Portune and D-Dalle.

The following acoustic rating information was sourced from O'Portune Technical Description (CBS-CBT, 2009b):

- R_W 53, $L_{n,w}$ 69 – 19mm OSB flooring on 12 mm elastomeric strips
- R_W 56, $L_{n,w}$ 62 – 19mm OSB flooring on 15 mm mineral wool
- R_W 54, $L_{n,w}$ 56 – 5 layers of 10mm plasterboard flooring on 40 mm thick polystyrene
- R_W 56, $L_{n,w}$ 49 – 4 layers of 10mm plasterboard flooring on 30 mm mineral wool on 12 mm OSB flooring
- R_W 59, $L_{n,w}$ 43 – 4 layers of 10mm plasterboard flooring on 30 mm mineral wool on 19mm OSB flooring on 12 mm elastomeric strips
- R_W 56, $L_{n,w}$ 51 – 50 mm concrete on 30 mm mineral wool

The following cross-section was obtained from Sandoz and Leistner (2006):

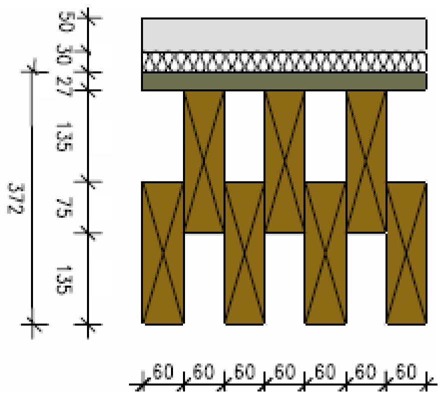


Figure 8.1 – Cross-section of O'Portune® Floor with 50 mm Concrete Topping

8.4.9 D-Dalle®

Sandoz and Leistner (2006) give a general comparison of sound performance properties for various timber floor systems, including vertical nailed plank, timber-concrete composite, O'Portune and D-Dalle.

The following acoustic rating information was sourced from D-Dalle Technical Description (CBS-CBT, 2009a):

- R_W 53, $L_{n,w}$ 84 – bare concrete floor
- R_W 61, $L_{n,w}$ 44 – add 2 layers of 10mm plasterboard flooring on 15 mm mineral wool
- R_W 63, $L_{n,w}$ 42 – add 3 layers of 10mm plasterboard flooring on 30 mm mineral wool

The following cross-section was obtained from Sandoz and Leistner (2006):

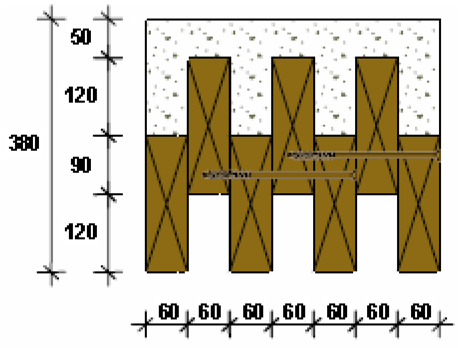


Figure 8.2 – Cross-section of D-Dalle® TCC with Bare Concrete Floor

8.4.10 Structural Insulated Panel (SIP)

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5 Under Development Timber Floor Systems

5.1 Timber-Concrete Composite (TCC)

5.2 Plywood Box Beam Joists

5.3 Stressed-Skin Panel (SSP)

5.4 Cross-Laminated Timber (CLT)

5.5 Vertical Nailed Plank (VPN)

5.5 Stress-Laminated Timber (SLT)

5.6 Refond Floor

8.5.1 Timber-Concrete Composite (TCC)

Schmid (2008) reports a lack of test information for acoustic field measurements of timber-concrete composite floors, and to address this, has outlined numerical correlations to estimate airborne and impact sound insulation values for eight timber-concrete composite floors. The findings gave a range of results: from 6.7 dB better than predicted to 3.1 dB worse than predicted for airborne sound values, from 1.8 dB better than predicted to 4.0 dB worse than predicted for impact sound values. Schmid (2008) concluded that these predictions can be made within plus or minus 3 dB.

The following cross-section was obtained from Schmid (2008):

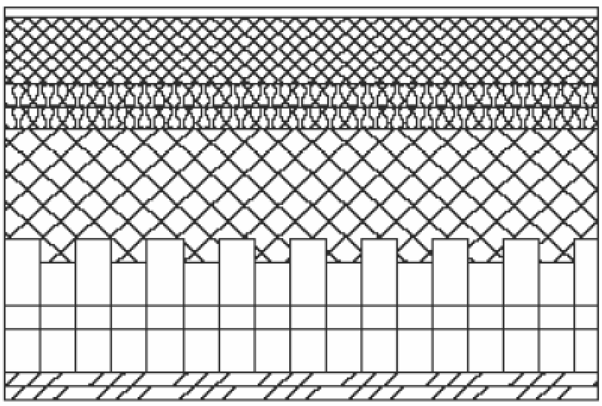


Figure 8.3 – Example of Acoustic Layers on TCC Floor

Note: Layer description was not available in reference.

8.5.2 Plywood Box Beam Joists

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5.3 Stressed-Skin Panel (SSP)

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5.4 Cross-Laminated Timber (CLT)

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5.5 Vertical Nailed Plank (VNP)

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5.6 Stress-Laminated Timber (SLT)

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

8.5.7 Refond Floor

- Information unavailable – not tested as yet
- Consider using GIB Noise Control Systems (Winstone Wallboards, 2006b)

9. Summary of Floor System Performance

This chapter summarises the structural, fire and acoustic performance aspects from the preceding chapters.

9.1 Timber Floors

The following table summarises indicative values for the span, fire and acoustic properties of timber floors. More detail is available in the preceding sections and in the associated references. Estimates are shown in **italics**.

Table 9.1 – Timber Floors, Overall Performance Summary

TIMBER FLOOR SYSTMES – OVERALL PERFORMANCE – 3.0 kPa LIVE LOAD							
SYSTEM	MAXIMUM SIMPLE SPAN (m)	JOIST SPACING (mm)	FRR	STC	IIC	MAXIMUM PRODUCT LENGTH (m)	REFERENCE
SAWN TIMBER	4.6	400	up to 90	38 to 58	31-46-50-72*	6.0	Winstone
GLULAM	9.5	1200	up to 90	38 to 58	31-46-50-72*	n/a	Winstone
HYSPAN LVL	9.9	400	up to 90	38 to 56	31-46-50-72*	12.0	Winstone
NELSON PINE LVL	9.2	400	up to 90	38 to 56	31-46-50-72*	12.0	Winstone
HYJOIST "I" JOIST	6.8	400	up to 90	38 to 56	31-46-50-72*	12.0	Winstone
LUMBERWORX "I" JOIST	6.0	400	up to 90	38 to 56	31-46-50-72*	9.0	Winstone
HYNE "I" JOIST	5.0	400	up to 90	38 to 56	31-46-50-72*	11.7	Winstone
PRYDA LONGREACH	7.2	400	up to 90	38 to 56	31-46-50-72*	n/a	Winstone
PRYDA SPAN	7.0	400	up to 90	38 to 56	31-46-50-72*	n/a	Winstone
POSI-STRUT	7.0	400	up to 90	38 to 56	31-46-50-72*	n/a	MiTek
HEBEL 75 mm POWERFLOOR	3.6	360	NIL 60	54 to 55 57 to 60	28-40-44-72* 31-42-47-75*	6.0	Hebel NZ
FLEXUS FLOOR	6.3	450	up to 90	38 to 57	35-47-51-81	n/a	Winstone
TECBEAM	7.5	400	up to 90	38 to 56	31-46-50-72*	n/a	Winstone
TECSLAB	6.8	400	up to 90	*54 to 55*	*28-40-44-72**	n/a	Hebel
POTIUS, NO CONC	8.0	600	up to 90	*26*	*20*	n/a	Kolb
POTIUS, NON-COMP CONC TOPPING	7.0	600	up to 90	*42*	*22*	n/a	Kolb
POTIUS, COMPOSITE CONC TOPPING	8.3	600	up to 90	*42*	*22*	n/a	Kolb
LIGNATUR	10.0	n/a	up to 90	49 to 72	*43 to 68*	16.5	Lignatur
WENUS	5.0	n/a	up to 90	-	-	6.0	CBS-CBT
O'PORTUNE	12.0	n/a	up to 120	53 to 59	*41 to 67*	n/a	CBS-CBT
D-DALLE	18.0	n/a	up to 90	53 to 63	*26 to 68*	n/a	CBS-CBT
STRUCTURAL INSULATED PANEL	5.4	1200	–	–	–	12.0	PBS
TTC COMPOSITE (UC)	9.0	1200	up to 120	*54 to 70*	*40 to 70**	n/a	O'Neill – Fire
PLYWOOD BOX JOISTS	8.0	400	up to 90	38 to 58	31-46-50-72*	n/a	Winstone
STRESS SKIN PANEL	10.0	600	up to 90	38 to 58	31-46-50-72*	n/a	Winstone
CROSS-LAMINATED	10.0	n/a	up to 90	*40*	*22*	12.0	Kolb
VERTICAL NAILED	*10.0*	n/a	*up to 90*	*40*	*22*	n/a	Kolb
STRESS-LAMINATED	*10.0*	n/a	*up to 90*	*40*	*22*	n/a	Kolb
REFOND ZIGZAG	4.8	n/a	–	–	–	n/a	Salmela

Note: This table summary should serve as a rough guide, and care should be taken, as values given are dependent upon specific materials and other variables. To achieve the highest IIC values shown with asterisks require carpet on 8 oz hard twist wool hessian backed carpet over rubber waffle underlay.

For lightweight timber floor systems where gypsum board ceilings would be standard practice, the fire and acoustic ratings are obtained from GIB Fire Rated Systems (Winstone Wallboards, 2006a) and GIB Noise Control Systems (Winstone Wallboards, 2006b). For fabricated floor panels the fire and acoustic ratings have been sourced directly from the manufacturer where available. For floor panels where acoustic information was not available, STC and IIC values have been inferred from Kolb (2008) and are given as a single value for the basic unit without any acoustic treatment.

9.2 Non-Timber Floors

The following table summarises indicative values for the span, fire and acoustic properties of non-timber floors. More detail is available in the preceding sections and in the associated references. Estimates are shown in **italics**.

Table 9.2 – Non-Timber Floors, Overall Performance Summary

NON-TIMBER FLOOR SYSTMES – OVERALL PERFORMANCE – 3.0 kPa LIVE LOAD							
SYSTEM	MAXIMUM SIMPLE SPAN (m)	UNIT WIDTH (mm)	FRR	STC	IIC	MAXIMUM PRODUCT LENGTH (m)	REFERENCE
FLAT SLAB & CONCRETE TOPPING	8.0	1200 2400	up to 90	55 to 58	28 to 75*	8.0	Stahlton & Stresscrete
RIB & INFILL & CONCRETE TOPPING	12.0	800 or 900 Centres	up to 90	53 to 56	28 to 75*	12.0	Stahlton & Stresscrete
HOLLOWCORE & CONCRETE TOPPING	18.0	1200	up to 120	49 to 67	28 to 75*	18.0	Stahlton & Stresscrete
DOUBLE “T” & CONCRETE TOPPING	18.0	2400	up to 90	53 to 59	28 to 75*	18.0	Stahlton & Stresscrete
STEEL DECK & CONCRETE TOPPING	8.7	Width Varies	up to 90	40 to 61	28 to 75*	8.7	Speedfloor
SPEED FLOOR & CONCRETE TOPPING	10.0	630 or 930 or 1230 Centres	up to 90	–	–	10.0	Speedfloor
HEBEL SUPERCRETE	5.5	600	up to 90	67	56 to 83	6.0	Hebel Aus

Note: This table summary should serve as a rough guide, and care should be taken, as values given are dependent upon specific materials and other variables. To achieve the highest IIC values shown with asterisks require carpet on 8 oz hard twist wool hessian backed carpet over rubber waffle underlay.

The following IIC values were obtained from Warnock (1999):

IIC 28	150 mm thick bare concrete floor
IIC 35-40	with vinyl flooring
IIC 30-35	with 9 mm hardwood flooring
IIC 45-50	with 9 mm hardwood flooring on 6 mm resilient layer
IIC 50-55	with 16 mm plywood flooring on strapping on 25 mm mineral fibre board
IIC 60-65	with 35 mm concrete on 25 mm mineral fibreboard
IIC 75-85	with carpet and underlay

10. Ceilings, Floor Underlays, Floor Coverings

This chapter outlines typical ceiling systems to protect the underside of floors and includes a floor underlay system that offers fire and acoustic performance.

10.1 Ceiling Systems

Ceilings are typically provided in most residential and office occupancies. Selected ceilings are normally either gypsum plasterboard with a smooth continuous finish or a suspended grid system with a modular layout. Both of these ceiling systems can provide various levels of fire and acoustic performance.

There are two distinct situations for the fire resistance of timber floor members, visible to show the natural aesthetics of timber, or enclosed with a ceiling material to gain fire and acoustic benefits. Ceiling linings can offer high levels of fire resistance to protect enclosed structural timber members. Ceiling also allow cavity on the underside of structural system to add material layers and air gaps to enhance the acoustic properties for the floor system and hide mechanical and electrical services. Alternatively, material layers and air gaps can be provided on the topside where the structural system is to remain visible on the underside.

Timber-concrete composite floor systems can have exposed timber joists and exposed timber soffit acting as permanent formwork for the concrete topping. The form of construction has been shown to resist fire beyond 60 minutes. A fire sprinkler system would provide a significant level of protection, however NZBC requires ceilings to comply with restrictive surface finishes while the wall finishes are relaxed when sprinklers are present. Further testing is required to ascertain whether sprinklers alone provide sufficient protection for visible timber structure, otherwise clear intumescent coatings will be required to satisfy the ceiling surface finish indices.

10.2 Floor Underlays

There is a fibre-reinforced gypsum floor underlay product available in New Zealand and Australia. This 10 mm nominal thickness product is identical in both countries, but marketed under different names:

- **GIB Sound Barrier® Timber** (in New Zealand)
- **USG Powerscape® Peace Timber™** (in Australia)

These tabulated values have been extracted from Airborne Sound versus Impact Sound graphs in Powerscape brochure (USG, 2005). The compliant value pairs to BCA requirements are shown in bold, while the compliant value pairs to NZBC requirements are shown shaded gray, with assumed relationship between L_n and IIC, by subtracting either value from 110 to obtain the other. This relationship does not hold true when maximum deficiency "8 dB rule" is applied to ISO rating.

Table 10.1 – GIB Noiseline® and/or GIB Sound Barrier®

VINYL FLOOR			
ACOUSTIC UNDERLAY	$R_W + C_{tr}$	$L'_{nT,w} + C_I$	CEILING LINING
None	47	62	1 layer 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	50	57	1 layer 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	53	55	1 layer 13mm GIB Noiseline
None	49	61	2 layers 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	53	57	2 layers 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	55	55	2 layers 13mm GIB Noiseline
TILE FLOOR			
ACOUSTIC UNDERLAY	$R_W + C_{tr}$	$L'_{nT,w} + C_I$	CEILING LINING
None	48	64	1 layer 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	51	57	1 layer 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	54	55	1 layer 13mm GIB Noiseline
None	50	62	2 layers 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	54	56	2 layers 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	56	53	2 layers 13mm GIB Noiseline
FLOATING TIMBER FLOOR			
ACOUSTIC UNDERLAY	$R_W + C_{tr}$	$L'_{nT,w} + C_I$	CEILING LINING
None	47	58	1 layer 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	50	57	1 layer 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	53	55	1 layer 13mm GIB Noiseline
None	49	58	2 layers 13mm GIB Noiseline
1 layer GIB Sound Barrier Timber	53	57	2 layers 13mm GIB Noiseline
2 layers GIB Sound Barrier Timber	55	54	2 layers 13mm GIB Noiseline

From these values it can be seen that twelve of these arrangements comply with BCA noise requirements, while only three of these comply with NZBC noise requirements. It can be seen that all but one of the eighteen tabulated arrangements comply with BCA impact noise requirements, that being $L'_{nT,w}$ + Cl = 64 for the worst case Tile Floor.

All of the values in the previous table were derived from the same floor construction:

- 19 mm Particleboard
- 200 mm x 50 mm timber joists at 450 mm centres
- 240 mm cavity
- Glass wool insulation (R2.5)
- Stud and track ST001 acoustic resilient mount
- Rondo Type 129 steel ceiling battens at 600 centres
- High density plasterboard, 12.2 kg/m² or higher

The insulation used in GIB Noise Control Systems (Winstone Wallboards, 2006b) is:

- 100 mm Pink Batts Silencer (R2.4) in their sub-inter-tenancy solutions
- 75 mm (revised product is 95 mm thick) Pink Batts (R1.8) in their inter-tenancy solutions

The Powerscape brochure (USG, 2005) recommends double layer of Powerscape Peace Timber (GIB Sound Barrier Timber in NZ) underlay in preference to double layer of 13 mm high-density plasterboard (13 mm GIB Noiseline in NZ) on the ceiling. However, there is no difference for airborne sound rating and a small (1 or 2) point value improvement for impact sound rating. Adding gypsum board ceiling layer instead of gypsum fibreboard floor underlay provides increased fire resistance in the normally considered direction, threat of fire from below. The added mass is a plus for acoustic and vibration properties and a negative for span capacity of a floor system.

Further investigation could be carried out using underlay products, including GIB fibre-reinforced gypsum floor underlay product called *GIB Sound Barrier Timber* (Winstone Wallboards, 2005), with a primary use as acoustic underlay on top of particleboard flooring and a secondary use as fire protection from above. Other tests should include the various floor coverings typically used, namely carpet, lino and ceramic tiles.

10.3 Floor Coverings

Whiting and Wade (1998) gave an overview of tests carried out at BRANZ on standard 20 mm particleboard flooring timber floors for fire attack from above. They advised floor overlay was not required for floor systems requiring fire resistance rating of 30 minutes or less, but would be required for floor systems requiring fire resistance rating of 60 minutes or more. Alternatively, the particleboard thickness could be increased. It was estimated that some carpets could increase the fire resistance up to 10 minutes.

The research into timber floors subjected to fire attack from above was initiated in response to the 1995 version of the New Zealand Building Code (NZBC) which required non-combustible floor overlays for fire resistance rating of 60 minutes or more (Whiting, 2003). However, this clause was modified in the 2001 version of the NZBC and remains current in the latest 2008 version of the NZBC (DBH, 2008). Clause 6.20.14: *In any fire cell which has a firecell below the flooring may be of wood products provided it has a thickness of no less than 20 mm*. Also, Clause 6.14.2: *Floors need to be rated only on the underside applicable to the fire cell directly below. The main threat to a floor is a fire beneath that floor.*

The sound absorption coefficient of carpet depends on the pile weight per unit floor area, pile height and type of backing material (Harris, 1994). Both wool and nylon carpets have similar performance and as a general rule cut pile has greater absorption than a looped pile. The sound absorption can be increased further with an underlay. This sound absorption is solely the reflective noise within a room.

Buchanan (2007) gives the example of a typical floor construction comprising particleboard flooring on timber joists with 13 mm gypsum board ceiling. Without carpet, the sound ratings achieved are IIC of 45 and STC of 47. The addition of carpet on a rubber pad underlay increases the impact sound insulation rating to IIC of 65, however the airborne sound insulation rating STC of 47 remains the same.

10.4 Raised Access Flooring

Raised access flooring is in prevalent use within commercial buildings throughout the United Kingdom to allow void for electrical cabling and other low profile services. Larger ducting and fire sprinklers are commonly located in the ceiling void. It may be possible to include an acoustic layer inside raised access flooring, particularly to combat impact noise. Bayne and Page (2009) have investigated new timber products for use in Australia, one of which is raised access flooring with a hardwood timber surface for use in office environments.

The use of raised access flooring could be considered when the underside of timber floor members remain visible, for instance case of timber-concrete composite floor systems or solid timber plate systems. It may be possible to include the acoustic layers along with the distribution of mechanical and electrical services. Sealed penetrations are required where wiring for lights and dropper pipes for sprinklers are located.

11. Timber Floor Systems in Buildings

This chapter includes a selection of timber buildings built in New Zealand and around the world, and examines the incorporated timber floor systems.

11.1 Nelson Marlborough Institute of Technology

The following photo was obtained from NZ Wood website (www.nzwood.co.nz):

Figure 11.1 – Artist Impression of Proposed NMIT Building in Nelson

The Nelson Marlborough Institute of Technology (NMIT) Arts & Media Centre building is the first approved Build-in-wood Demonstration Building under a New Zealand Government initiative. Construction of this building commenced towards the end of 2009. The design consultants for the NMIT project are Aurecon (formerly Connell Wagner). This is an all-timber building structure comprising timber floors with non-composite concrete topping supported on timber columns and shear walls. The shear walls provide the lateral stability for wind and seismic loads.

The Potius timber floors, maximum span 5.6 m carry 75 mm non-composite concrete topping on 1200 mm wide 36 mm thick LVL timber floor plate on 400 mm deep x 90 mm wide LVL beams, two per 1200 mm wide unit. These floors are flange hung to minimise the overall depth at floor to primary beam junction. The floors have screw connectors added to the fully glued interface between the joist and plywood top skin, to prevent unzipping of these elements at the end supports.

The floors have been designed for 30 minutes fire resistance, based on fully sprinklered building allowing F30 rating, while an S rating is not required for this building, as it is remote from neighbouring boundaries and other buildings. Due to the non-complying plywood ceiling surface finish, this building has two rows of sprinklers to provide upwards water spray for protection of ceiling and downwards water spray for protection of the building and contents.

For transmission acoustics, the airborne rating will be less than STC 55 as there is no ceiling, and the impact rating will be less than IIC 55 as there is no carpet. The selected flooring product will be cushion-backed vinyl to provide a robust and slip resistant surface to cater for the intended activities. To assist with reverberation acoustics of the ceiling, every second gap between visible timber joists will have an acoustic product infill to reduce the reflective sound, the alternating gaps will show the underside of the plywood top skin.

11.2 Other Case Study Timber Buildings

11.2.1 Martin Square Apartments in Wellington

The following photo was obtained from website:

(media.point2.com/p2a/htmltext/b827/e35a/e69b/893dbf200bcaaf752865/original.jpg)

Figure 11.2 – Photo of Martin Square Apartments in Wellington

Built in 2004, Martin Square Apartments building was designed by Don Jamieson Architecture and Holmes Consulting. The building includes 17 two-bedroom apartments and 88 studio apartments, all furnished and self contained, primarily for student accommodation as well as investor owners. The construction consists of six-storey timber framed accommodation on reinforced concrete base level of for car parking.

The smaller room dimensions allowed the use of plywood timber bracing panels to resist later loads, with supplementary steel "K" braces to provide torsional restraint around the perimeter walls. It is clad in Hardies ExoTec façade panel, which is manufactured from high-density cement. The project was programmed to take 14 months but was completed 4 months ahead of schedule at a cost of $NZ 5.8 million.

Each floor is approximately 650 m² and is constructed with 19 mm plywood flooring on Hyne timber "I" joists, spanning approximately 4 m. The joists were originally marketed by Origin Timber, now marketed by Engineered Timber Solutions. The lateral load distribution was calculated for both rigid and flexible diaphragm cases, and the greater from these was applied to each individual shear wall (Milburn and Banks, 2004).

For the main floors, a standard GIB Noise Control System GBDFA (Winstone Wallboards, 2006b) was used to achieve 60 minute fire rating and STC 55 minimum airborne noise rating. Vinyl floor coverings were used in the bathroom and kitchen areas and polypropylene carpet on underlay was used elsewhere. GIB Sound Barrier Timber (Winstone Wallboards, 2005) acoustic floor underlay was considered, but not used. A special detail was used for stairwell landings to reduce impact noise from these using 19 mm particleboard set down between 200 mm x 50 mm sawn timber joists to support 100 mm of sand beneath the 19 mm plywood flooring.

The following photo was obtained from NZ Wood website www.nzwood.co.nz:

Figure 11.3 – Photo of Martin Square Apartments "I" Joist Floor

11.2.2 Stadthaus in Murray Grove, London

The following photo and information were obtained from The Wood Awards website (www.woodawards.com/the-stadthaus):

Figure 11.4 – Photo of Stadthaus in London, Murray Grove

The recently built Stadthaus in Murray Grove, London, is a nine storey high rise building providing 29 apartments and has been described as the tallest timber residential building in the world. This all timber building was designed by Waugh Thistleton Architects in conjunction with Techniker Structural Engineers. The project was completed 5 months ahead of schedule, the main structure erected in just over 2 months.

The building is constructed using cross-laminated timber panels from KLH UK for the walls and floors as well as the lift and stair cores. The cross-laminated timber panels are made of strips of European White Wood glued together to form a solid timber elements. This construction was well suited to the residential apartment layouts, with multiple rooms providing numerous walls for support. The panels are prefabricated including preformed openings for windows and doors.

Each floor is supported by walls beneath, with wall layout repeating up the building to allow direct transfer of vertical loads. The timber structure is untreated, with exterior cladding providing protection from the outside elements using Eternit fibre cement façade panels. The acoustic separation between floors is achieved using floor build-up above and ceiling cavity with insulation below.

The following cross-section was obtained from Lowenstein (2008):

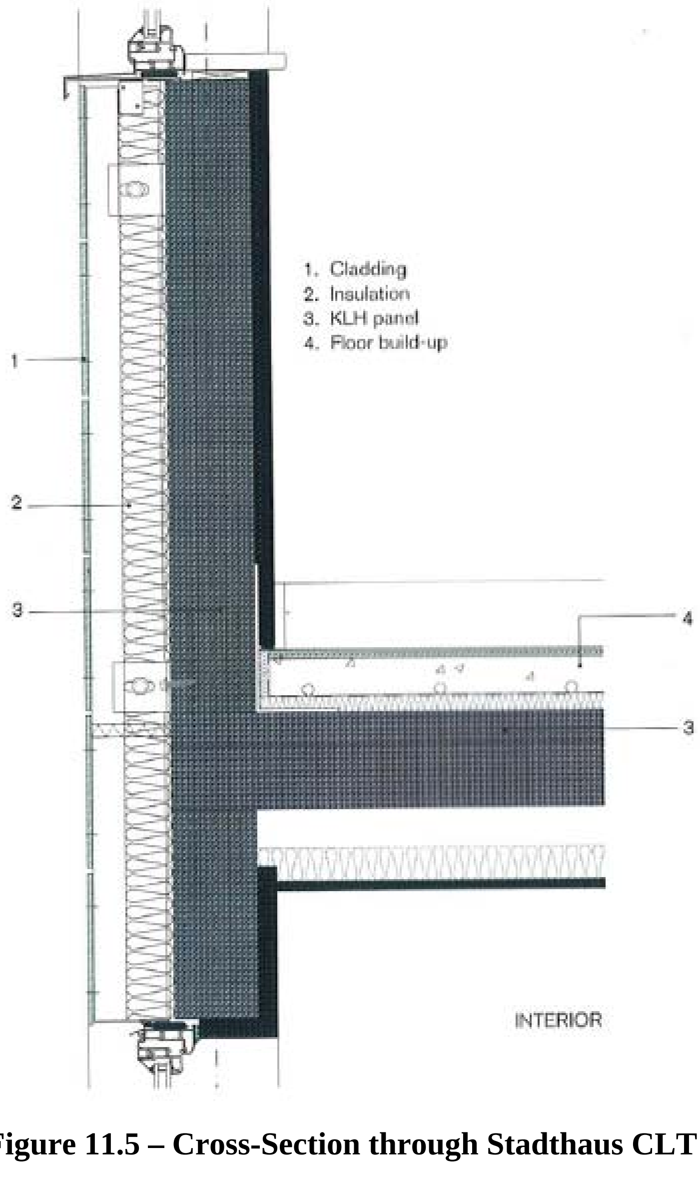


Figure 11.5 – Cross-Section through Stadthaus CLT Floor to Wall Junction

11.2.3 Mossbourne Community Academy in Hackney

The following photo and information were obtained from website (www.bdonline.co.uk/story.asp?storycode=3117947):

Figure 11.6 – Photo of Ramboll Whitbybird TCC Floor

The Mossbourne Community Academy timber building located in Hackney, East London incorporates non-composite timber-concrete floors. The Engineers for this project, Ramboll (formerly Ramboll Whitbybird) have further developed a timber-concrete composite floor system in conjunction with Cambridge University. Full-scale load tests have been conducted on floors comprising of 130 mm concrete on steel tray spanning onto 550 mm deep glulam whitewood timber beams with shear connection between the concrete and the timber. The shear connection is 16mm diameter by 130 mm long threaded bolts inclined towards the direction of the supports.

The steel tray provides permanent formwork and in-service strength for the poured concrete topping. The timber beams have been designed to allow for 60 minutes of charring, while the steel tray will provide protection from concrete spalling off during a fire. A precast concrete alternative was considered, however lifting of the precast panel into place and the complexity of grouting bolt connections took considerable time and effort. The cast in-situ solution however makes deconstruction more difficult.

The research found the composite section to have twice the strength and three times the stiffness than the non-composite timber beam allowing a reduced overall depth of floor section. Their optimal span for this floor system was found to be in the order of 7.5 m to 9.0 m, and was recommended for schools, open-plan offices and libraries. It is claimed the floor is robust and suitable for vibration-sensitive activities. Considerable time was spent on study of timber effects, such as creep, shrinkage, changeable moisture content and differential thermal expansion compared to concrete.

Only the non-composite floor has been used, the proposed timber-concrete composite is planned for use in a car-park building. Further evaluation of the system has been conducted by Ramboll in conduction with East Anglia University, with a spreadsheet developed to aid design of these floors.

The following graphic was obtained from website address:
(www.bdonline.co.uk/story_attachment.asp?storycode=3117947&seq=4&type=G&c=1)

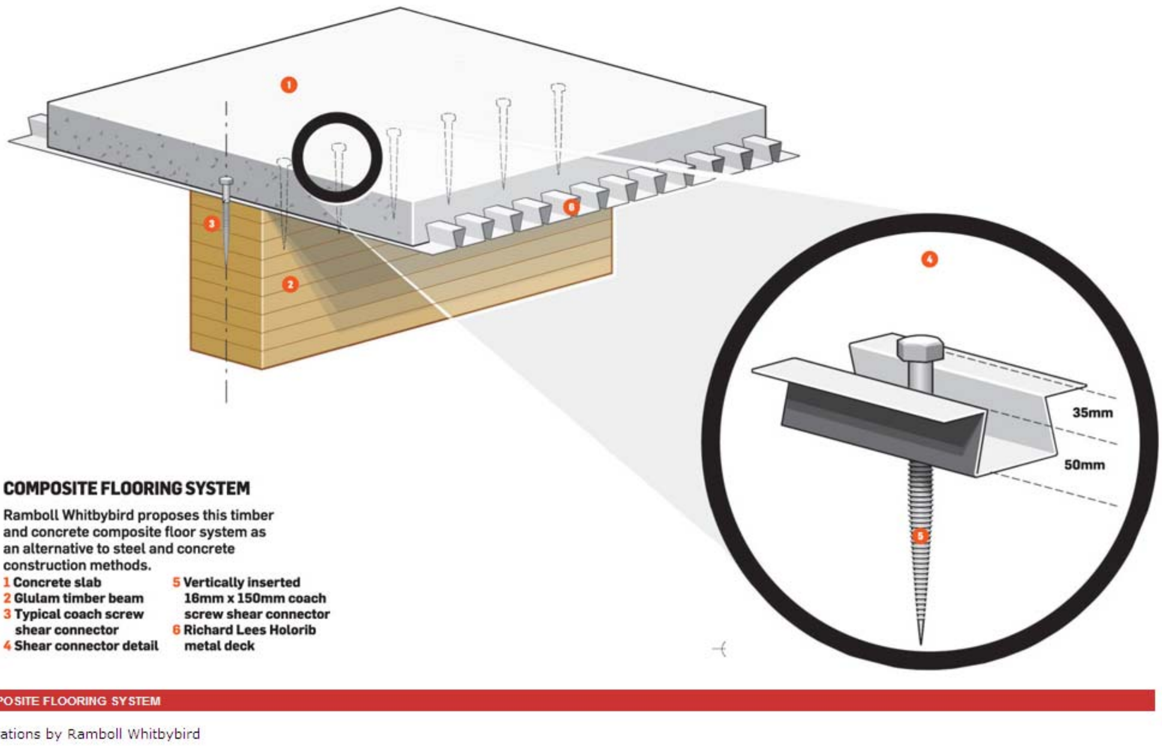


Figure 11.7 – Graphic of Ramboll TCC Floor

11.2.4 Limnologen 8-Storey Timber Houses

The following photo and information were obtained from website address: (http://mpd.midroc.se/en/References/Limnologen.aspx)

Figure 11.8 – Photo of Limnologen 8-Storey Timber Houses in Sweden

The Limnologen development comprises **four** 8-storey timber houses, each with 33 or 34 apartments, 134 apartments in total. Built by Martinsons Byggsystem of Sweden, the construction period was less than 3 years with mid-2009 project completion. The development is located by Lake Trummen in Växjö, and these are the tallest all-timber buildings currently in Sweden. The floors and main walls of the building are constructed using cross-laminated timber, except for the first floor which is constructed using reinforced concrete transfer slab, and some of the internal walls are light timber framed.

The flooring used in this building is termed “Cassette Floors” in Zeng, Ren and Sabri (2009). The make-up of the floor is cross-laminated timber with inverted “T” timber sections glued to the upper part for greater strength and stiffness. The gypsum board ceiling provides fire resistance and is independently supported to reduce acoustic transmission. The floor coverings include floating timber floor on acoustic underlay with provision for under-floor heating. More information of this product is located in Solid Wood Handbook (Martinsons Byggsystem, 2006)

The following graphics were obtained from Zeng, Ren and Sabri (2009):

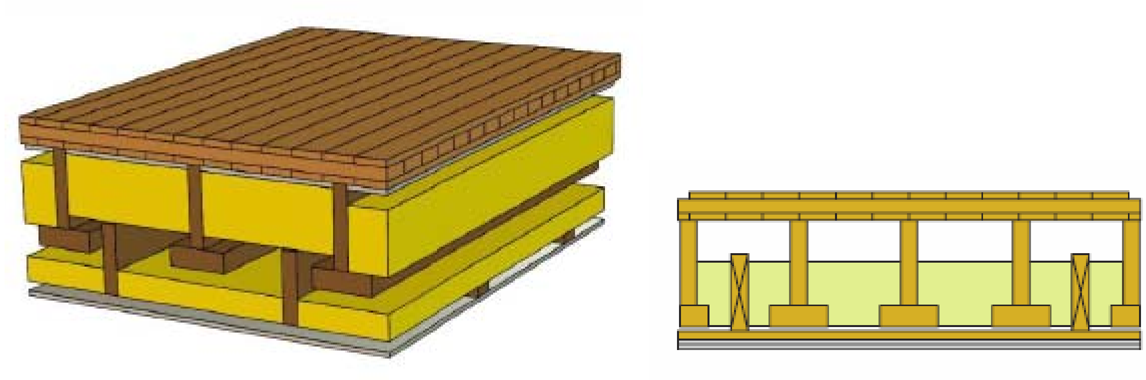


Figure 11.9 – Graphic and Cross-Section of Limnologen CLT Floor

12. Conclusions

There is significant interest globally regarding timber floor systems, especially timber-concrete composite floor systems for their increased span capacity, and cassette floor systems for their faster installation on site. The main drivers for using timber in floors is the global shift towards using more sustainable products in buildings, and the weight savings achievable due to the high strength-to-weight ratio of timber. This reduced weight benefit has a flow-on effect to other parts of the structure, particularly the restraint structure for lateral seismic loads and reduced foundations. This also means less weight of materials transported to site and easier handling on site.

This report has outlined a range of timber and timber-concrete composite floor systems to identify their ability to perform in buildings where previously steel and concrete combinations dominated. There is a wide range of timber floors systems, from simple timber floor joist with timber flooring and gypsum ceilings, through to more complex systems with an array of added material layers to provide fire resistance and acoustic performance.

The timber-concrete composite floor systems provide the greatest potential benefits due to their effective use of timber and concrete material properties. The timber component offers a high strength-to-weight ratio, visual aesthetics and increased damping to resist vibration while the concrete component offers increased fire resistance, acoustic performance and thermal mass. Each of these materials is functioning in their ideal modes, with timber in tension and concrete in compression, providing a stronger/stiffer section for increased spans. The composite concrete topping adds weight to the floor system, however this is offset by the structural, fire and acoustic benefits.

Concrete and concrete-steel floor products are included to demonstrate that timber floor systems are often comparable, and provide further direction for the development of timber floor systems. Concrete can be formed into various shapes with continuously connected monolithic construction achieved using cast in-situ joints. Concrete floors have been the benchmark for longer span floor solutions and users are comfortable with the inherent fire resistance and acoustic performance that concrete can offer. Concrete is a non-combustible material, however spalling can be an issue when subjected to fire temperatures. Timber is combustible, however the charring rate is predictable and insulation from timber char minimised the temperature affected depth.

Concrete is a “wet” trade, which requires temporary formwork, propping, pouring and time to set and cure. Timber floors without concrete topping have several benefits in construction. As a “dry” trade, most of the work can be carried out by on-site Carpenters, reducing the requirement for additional trades to install. This reduces the on-site coordination and increases the speed of construction. Prefabricated timber floor units allow even quicker installation and provide a stable working platform for added safety.

Timber-concrete composite floors are heavier than timber only floors but lighter than concrete only floors. The “wet” trade aspect of the concrete topping is the same for timber-concrete composite floor systems and precast concrete floor systems. However, fully prefabricated timber-concrete composite floor systems have also been investigated, to retain the benefits of dry installation. The prefabrication of timber and timber-concrete composite floor systems is likely to become more prevalent, with reduced on-site installation time leading to on-site labour cost savings. The efficiency and economics of prefabrication should be considered, as well as improved quality control.

Concrete, when cast monolithically and with steel reinforcing in both directions, offers two-way span action, compared with one-way span action for most timber floor systems. Cross-laminated timber has the potential for two-way span, except the width of this product is limited by fabrication and transportation practicalities. Of the timber floor systems, only stress-laminated timber can offer potential two-way span action, however this product is not typically used for floors in buildings, and is primarily for timber bridges. The increased transverse stiffness improves vibration characteristics of timber floor systems. Thermal mass is one of concretes major benefits, however the mass needs to be accessible in order to be effective, while floor coverings and ceilings reduce the accessibility.

An overview of New Zealand and Australia building code requirements for floor systems highlights the similarity between their objectives, function statements, and performance requirements. The New Zealand and Australian procedures to satisfy structural and acoustic aspects are very similar. However, there are significant differences between the New Zealand and Australian prescriptive rules to obtain fire compliance. The Australian deemed-to-satisfy provisions typically require greater fire resistance times, compared with the New Zealand acceptable solution. This difference will have some influence over specific fire design approaches in each country, particularly when attempting to derive a fire safety solution with an equivalent risk to that offered by the applicable prescriptive rules.

It is possible to design for the fire exposed underside of heavy timber floor systems and timber-concrete composite floor systems by determining the loss of timber section based on experimentally derived charring rates. The biggest hurdle is timber ceilings are typically not permitted as a compliant surface finish even if sprinklers are installed, although timber beams are allowed. Further research is required to overcome this issue so that timber can remain visible for aesthetics, assuming acoustic control can be provided without the need for a ceiling.

For light and heavy timber systems, gypsum board ceilings offer relatively simple solutions with dependable fire ratings, while the acoustic arrangements require more comprehensive detailing, often with the addition of resilient rails and in-void insulation to meet minimum noise reduction levels. The level of complexity of acoustic detailing increases significantly to achieve modest improvement to these minimum levels. In particular, low frequency impact noise appears to be the most problematic sound to cater for. Most of the proposed designs to combat impact noise address the issue directly at the source with greater mass and/or isolation at the upper surface, such as concrete topping, sand ballast or floating floors, or by adding carpet.

Both timber and concrete floor systems require attention to detail to combat impact noise. Timber floors are susceptible to the lower frequency impact and vibration which are often an issue. Acoustically, concrete can be simpler to satisfy, while timber often requires more material layers to resolve. Manufacturers of all types of floor systems often recommend carpet as a solution for impact noise, as the carpet on underlay offers significant improvement to impact noise effects. However, carpet is not practical in kitchen and bathroom areas where ceramic tiles, vinyl or floating timber floors are typically used. Additionally, the owner/occupier often selects the floor coverings, and may not use carpet at all. Floor systems may need to be designed on the basis that carpet is not present, therefore compliant floor systems will need to incorporate other floor coverings.

Several of the timber-concrete composite floor systems have permanent plywood formwork which presents the issue of non-complying timber ceiling surface finishes. A system similar to Speedfloor could be devised, with reusable formwork readily attached before pouring concrete, and detached after concrete has cured. The use of permanent steel tray on timber joists was used recently in the United Kingdom and this option would address the issue of concrete spalling when exposed to fire temperatures. Both these alternatives remove the timber ceiling surface finishes issue, and provide direct accessibility to the thermal mass of the concrete from above or below.

There appears to be a move towards timber "cassette" floor systems with several new timber "cassette" floor systems identified. Most of these are semi-prefabricated and require installation of gypsum board ceilings after positioning on site, while a few arrive to site fully prefabricated. It is interesting that various timber "cassette" floor systems have different approaches to the finished look. The Swedish floor system by Martinsons Byggsystem covers all of the timber structure with gypsum board ceiling while the Swiss system by Lignatur has a high quality visible timber finish.

The production of these new timber and timber-concrete composite floor systems follow a natural design progression. Initial calculations and physical testing are conducted for the structural aspects of strength and deflection, with fire, acoustic and vibration aspects subsequently explored. The three primary aspects of structural, fire and acoustics are essential when establishing a new floor product, however many new products have mostly structural information and the designer is directed elsewhere for fire and acoustic solutions. For existing commercial systems, fire and acoustic are often achieved using gypsum board linings. Systems need to be considered as a whole, structural capacity, fire resistance, acoustic insulation, vibration, constructability, economics, and environment.

Increasingly, calculations for more complex structural systems like timber-concrete composite floors are conducted using finite element methods. The finite element models are correlated against small-scale component tests and full-scale floor tests to allow simplified formula to be derived. Finite element modelling is particularly relevant when fire aspects are considered. The issue of vibration is not fully resolved and the calculations involve complex mathematical models. There are simplified rules vibration criteria, however the method used in Australasia is a less than North American criteria.

Further testing of recently introduced floor solutions is required, new innovative systems and refinement of current systems is likely. Design information needs to be accessible to allow adoption of these new systems. Initially this will come directly from the Universities for use by Structural Engineers and eventually from the Manufacturers for use by Architects and Designers. A planned approach is required to incorporate structural, fire, acoustic and long-term creep deflection testing. Timber floors can offer the requisite performance levels and benefits to the overall structure. The popularity of a floor system will depend largely on its performance, economic and environmental attributes, coupled with ease of construction for built on site solutions, or installation of prefabricated systems.

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Europe

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www.vxu.se	Växjö University, Sweden (now Linnaeus University)

United Kingdom

www.cte.napier.ac.uk	Centre for Timber Engineering, Napier University
www.innovaresystems.co.uk	Innovaré Systems (SIPs manufacturer)
www.cibworld.nl	International Council for Research and Innovation in Building and Construction
www.klhuk.com	KLH UK Ltd
www.trada.co.uk	Timber Research and Development Association
www.woodawards.com	The Wood Awards
www.woodforgood.com	Wood for Good (UK wood promotion campaign)

United States of America

www.afandpa.org	American Forest & Paper Organisation (AF&PA)
www.aitc-glulam.org	American Institute of Timber Construction (AITC)
www.apawood.org	APA – The Engineered Wood Association (formerly the American Plywood Association)
www.awc.org	American Wood Council
www.inhabitat.com	Inhabitat – *Design Will Save the World*
www.i-joist.org	Wood I-Joist Manufacturers Association (WIJMA)
www.ewpa.com	Engineered Wood Products Association
www.nfpa.org	National Fire Protection Association
www.pbssips.com	Premier Building Systems (SIPs manufacturer)
www.sfpe.org	Society of Fire Protection Engineers
www.nist.gov	National Institute of Standards and Technology
www.sbcindustry.com	Structural Building Components Association (SBCA)
www.sips.org	Structural Insulated Panel Association (SIPA)
www.woodworks.org	WoodWorks for Non-residential Construction
www.woodtruss.com	Wood Truss Council of America (WTCA)

Canada

www.cmhc-schl.gc.ca	Canada Mortgage and Housing Corporation
www.cwc.ca	Canadian Wood Council
www.naturallywood.com	Forestry Innovation Investment, British Columbia
www.nrc-cnrc.gc.ca	National Research Council Canada

Appendix A

NZBC C/AS1	**Tables 4.1/1 to 4.1/5**	**Fire Safety Precaution**
NZBC C/AS1	**Table 5.1**	**S Ratings**

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Table 4.1: Fire Safety Precautions
Key to table references

Part 3	Paragraphs 3.1.5, 3.13.1 and 3.19.2
Part 4	Paragraphs 4.3, 4.3.1, 4.3.3, 4.4.1, 4.5.2, 4.5.3, 4.5.4, 4.5.7, 4.5.8, 4.5.9, 4.5.10, 4.5.13, 4.5.14, 4.5.15, 4.5.19
Part 5	Paragraphs 5.5.1, 5.6.6, 5.6.8, 5.9.4 (c)
Part 6	Paragraphs 6.2.1, 6.4.1, 6.7.1, 6.8.1, 6.8.5, 6.8.6, 6.10.1, 6.11.1, 6.15.1, 6.19.9, 6.21.2, 6.23.1 (d), 6.23.2, 6.23.3
Part 8	Paragraphs 8.2.1, 8.2.2, 8.2.3
Appendix A	Paragraphs A1.1.1 and A1.1.2

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Fire safety precautions

Type	Description
1	Domestic smoke alarm system.
2	Manual fire alarm system.
3	Automatic fire alarm system with heat detectors and manual call points.
4	Automatic fire alarm system with smoke detectors and manual call points.
5	Automatic fire alarm system with modified smoke/heat detection and manual call points.
6	Automatic fire sprinkler system with manual call points.
7	Automatic fire sprinkler system with smoke detectors and manual call points.
8	Voice communication system.
9	Smoke control in air handling system.
10	Natural smoke venting.
11	Mechanical smoke extract.
12	No Type 12 currently specified.
13	Pressurisation of safe paths.
14	Fire hose reels.
15	Fire Service lift control.
16	Visibility in escape routes.
17	Emergency electrical power supply.
18	Fire hydrant system.
19	Refuge areas.
20.	Fire systems centre.

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Special applications

a Not required where:
- i) the *escape routes* serve an *occupant load* of no more than 50 in *purpose groups* CS (excluding *early childhood centres*), CM, WL, WM, WH and WF, or
- ii) the *escape routes* are for *purpose group* SA and serve no more than 10 beds, (or 20 beds for trampers huts, see Paragraph 6.20.6), or
- iii) exit doors from *purpose group* SA and SR *firecells* open directly onto a *safe place* or an external *safe path* (see Paragraph 3.14).

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b Where only a single *escape route* is available, no less than a Type 4 alarm is required. See Paragraph 3.15.3 for situations where sprinklers are required.

c Required where Fire Service hose run distance, from the Fire Service vehicular access (see Paragraph 8.1.1) to any point on any floor, is greater than 75 m.

e The smoke detection element is Type 5 within *firecells* containing sleeping accommodation. (See Appendix A for description of Type 5.)

f A direct connection to the Fire Service is not required provided a telephone is installed and freely available at all times to enable 111 calls to be made.

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Note:
The numbered references are more fully explained in Appendix A. Throughout Table 4.1 dark shading identifies where sprinklers are required.

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Table 4.1/1: Fire safety precautions for active purpose group firecells Occupant load 100

<table>
<tr><th></th><th></th><th colspan="11">Escape height</th></tr>
<tr><th>Purpose group</th><th>FHC</th><th>0 m (or single floor)</th><th colspan="2"><4 m (or two floors)</th><th colspan="2">4 m to <10 m</th><th colspan="2">10 m to <25 m</th><th>25 m to <34 m</th><th>34 m to <46 m</th><th>46 m to <58 m</th><th>over 58 m</th></tr>
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<tr><td>(Note 5)</td><td>4</td><td>F0</td><td></td><td>F30</td><td></td><td>F30</td><td></td><td>F45</td><td>F45</td><td>F60</td><td>F60</td><td>F90</td></tr>
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<tr><td>WM</td><td>2</td><td>F0</td><td>F60</td><td></td><td>F60</td><td></td><td>F60</td><td></td><td>F45</td><td>F45</td><td>F60</td><td>F90</td></tr>
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</table>

Amend 7 Nov 2008

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Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraphs 5.6.12 and 5.6.13 for concessions for *FHC* 4.
6. **Visibility in escape routes:** is specified in NZBC Clause F6.

Amend 4 Oct 2005

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Table 4.1/2: Fire safety precautions for active purpose group firecells Occupant load 101 to 500

Amend 5 Oct 2005

Amend 7 Nov 2008

Purpose group	FHC	Escape height: 0 m (or single floor)	<4 m (or two floors)		4 m to <10 m		10 m to <25 m		25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
CL	1	**F0**	**F45**		**F45**		**F45**		**F30**	**F45**	**F45**	**F60**
(Note 7)	2	**F0**	**F60**		**F60**		**F60**		**F45**	**F45**	**F60**	**F90**
	3	**F0**	**F60**		**F60**		**F90**		**F45**	**F60**	**F60**	**F90**
		3f 16 18c	3f 16 18c		3b 9 16 18c		4 9 16 18		6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 17 18 19 20
CM	2	**F0**	**F60**		**F60**		**F60**		**F45**	**F45**	**F60**	**F90**
(Note 5)	4	**F0**		**F30**		**F30**		**F45**	**F45**	**F60**	**F60**	**F90**
		3f 16 18c	3f 16 18c	6 16 18c	3b 9 16 18c	6 9 16 18c	3b 9 15 16 18	6 9 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18 20	7 9 13 15 16 18 20	7 9 13 15 16 17 18 19 20
WL	1	**F0**	**F45**		**F45**		**F45**		**F30**	**F45**	**F45**	**F60**
WM	2	**F0**	**F60**		**F60**		**F60**		**F45**	**F45**	**F60**	**F90**
WH	3	**F0**	**F60**		**F60**		**F90**		**F45**	**F60**	**F60**	**F90**
(Note 5)	4	**F0**		**F30**		**F30**		**F45**	**F45**	**F60**	**F60**	**F90**
		3f 16 18c	3f 16 18c	6 16 18c	3b 16 18c	6 16 18c	3b 15 16 18	6 15 16 18	6 15 16 18	6 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	**F0**	**F30**		**F30**		**F45**		**F45**	**F60**	**F60**	**F90**
		3f 16 18c	6 16 18c		6 16 18c		6 15 16 18		6 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2		3		4		5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells.*
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraphs 5.6.12 and 5.6.13 for concessions for *FHC* 4.
6. **Visibility in escape routes:** is specified in NZBC Clause F6.
7. **CL:** For *firecells*, which are not cinemas or *theatres*, with *escape height* less than 4.0 m and *occupant load* not greater than 250, Type 2f is a permitted alternative to Type 3f.

Amend 7 Nov 2008

Amend 4 Nov 2008

Table 4.1/3: Fire safety precautions for active purpose group firecells Occupant load 501 to 1000

Amend 5 Oct 2005
Amend 7 Nov 2008

<table>
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<tr><th>Purpose group</th><th>FHC</th><th>0 m (or single floor)</th><th colspan="2"><4 m (or two floors)</th><th colspan="2">4 m to <10 m</th><th>10 m to <25 m</th><th>25 m to <34 m</th><th>34 m to <46 m</th><th>46 m to <58 m</th><th>over 58 m</th></tr>
<tr><td>CL</td><td>1</td><td>F0</td><td colspan="2">F45</td><td colspan="2">F45</td><td>F30</td><td>F30</td><td>F45</td><td>F45</td><td>F60</td></tr>
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<tr><td>(Note 5)</td><td>4</td><td>F0</td><td></td><td>F30</td><td></td><td>F30</td><td>F45</td><td>F45</td><td>F60</td><td>F60</td><td>F90</td></tr>
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<tr><td>WM</td><td>2</td><td>F0</td><td>F60</td><td></td><td>F60</td><td></td><td>F30</td><td>F45</td><td>F45</td><td>F60</td><td>F90</td></tr>
<tr><td>WH</td><td>3</td><td>F0</td><td>F60</td><td></td><td>F60</td><td></td><td>F45</td><td>F45</td><td>F60</td><td>F60</td><td>F90</td></tr>
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</table>

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* an *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraphs 5.6.12 and 5.6.13 for concessions for *FHC* 4.
6. **Visibility in escape routes:** is specified in NZBC Clause F6.

Amend 4 Oct 2005

Amend 7 Jun 2008

Amend 4 Oct 2005

Table 4.1/4: Fire safety precautions for active purpose group firecells Occupant load over 1000

Amend 7 Nov 2008

		Escape height							
Purpose group	**FHC**	**0 m (or single floor)**	**<4 m (or two floors)**	**4 m to <10 m**	**10 m to <25 m**	**25 m to <34 m**	**34 m to <46 m**	**46 m to <58 m**	**over 58 m**
CL	1	**F0**	**F30**	**F30**	**F30**	**F30**	**F45**	**F45**	**F60**
	2	**F0**	**F30**	**F30**	**F30**	**F45**	**F60**	**F60**	**F90**
	3	**F0**	**F30**	**F30**	**F45**	**F45**	**F60**	**F60**	**F90**
		7 16 18c	7 16 18c	7 9 16 18c	7 9 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 17 18 19 20
CM	2	**F0**	**F30**	**F30**	**F30**	**F45**	**F45**	**F60**	**F90**
(Note 5)	4	**F0**	**F30**	**F30**	**F45**	**F45**	**F60**	**F60**	**F90**
		7 16 18c	7 16 18c	7 9 16 18c	7 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 20	7 9 13 15 16 18 20	7 9 13 15 16 17 18 19 20
WL	1	**F0**	**F30**	**F30**	**F30**	**F30**	**F45**	**F45**	**F60**
WM	2	**F0**	**F30**	**F30**	**F30**	**F45**	**F45**	**F60**	**F90**
WH	3	**F0**	**F30**	**F30**	**F30**	**F45**	**F60**	**F60**	**F90**
(Note 5)	4	**F0**	**F30**	**F30**	**F30**	**F45**	**F60**	**F60**	**F90**
		7 16 18c	7 16 18c	7 16 18c	7 15 16 18	7 15 16 18	7 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	**F0**	**F30**	**F30**	**F45**	**F45**	**F60**	**F60**	**F90**
		7 16 18c	7 16 18c	7 16 18c	7 15 16 18	7 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2	3	4	5	6	7	8

Amend 7 Nov 2008

Amend 7 Nov 2008

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraphs 5.6.12 and 5.6.13 for concessions for *FHC* 4.
6. **Visibility in escape routes:** is specified in NZBC Clause F6.

Amend 7 Nov 2008

Table 4.1/5: Fire safety precautions for sleeping purpose group firecells
Occupant load 40 maximum

Purpose Group	FHC	Escape height: 0 m (or single floor)	<4 m (or two floors)	4 m to <10 m	10 m to <25 m	25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
SC **SD**	1	**F0**	**F30**	**F30**	**F30**	**F30**	**F45**	**F45**	**F60**
		7 16 18c	7 16 18c	7 16 18c	7 9 15 16 18	7 8 9 13 15 16 18 20	7 8 9 13 15 16 18 20	7 8 9 13 15 16 18 20	7 8 9 13 15 16 17 18 19 20
SA **(Note 5)**	1	**F0**	**F45**	**F45**	**F45**	**F30**	**F45**	**F45**	**F60**
		5af 16 18c	5f 16 18c	5 14 16 18c	5 14 15 16 18	7e 8 9 15 16 18	7e 8 9 13 15 16 18 20	7e 8 9 13 15 16 18 20	7e 8 9 13 15 16 17 18 20
SR **(Note 7)**	1	**F0**	**F45**	**F45**	**F45**	**F30**	**F45**	**F45**	**F60**
		1 16	1 2af 16	1 2f 16	5 14 16 18	7e 15 16 18	7e 15 16 18	7e 15 16 18 20	7e 13 15 16 18 20
Column		1	2	3	4	5	6	7	8

Amend 7 Nov 2008

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** *Purpose group* SA may have an *occupant load* up to 160 beds in *firecells* with a Type 7 alarm (see Paragraph 6.7.2).
6. **Occupant load in SC and SD firecells:** The *occupant load* in a *group sleeping area firecell* is limited to 12 or 20 beds and in a *suite* to six beds (see Paragraphs 6.6.3 to 6.6.5). For *firecells* (such as an operating theatre) required to remain occupied during a *fire*, see Paragraphs 5.6.8 and 5.6.9.
7. **SR household units:** See Paragraph 6.8.6 which describes where *household units* containing upper floors may be treated as single floor *firecells*.
8. **Visibility in escape routes:** is specified in NZBC Clause F6.

Amend 4 Oct 2005

Amend 7 Nov 2008

Table 5.1: Values of t_e for Calculating the S Ratings for Fire Hazard Categories 1, 2 and 3
Paragraphs 2.2.1, 5.5.2, 5.5.3, 6.10.5, 6.20.15

	Fire Hazard Category 1 (FLED = 400 MJ/m²)					Fire Hazard Category 2 (FLED = 800 MJ/m²)					Fire Hazard Category 3 (FLED = 1200 MJ/m²)				
	A_h/A_f					A_h/A_f					A_h/A_f				
A_v/A_f	0.00	0.05	0.10	0.15	0.20	0.00	0.05	0.10	0.15	0.20	0.00	0.05	0.10	0.15	0.20
0.05 or less	90	60	50	40	40	180	120	100	80	80	240	180	140	140	120
0.06	80	50	50	40	40	160	110	90	80	80	240	160	140	120	110
0.07	70	50	40	40	40	150	100	80	80	70	220	160	140	120	110
0.08	70	50	40	40	30	140	90	80	70	70	220	140	120	110	100
0.09	60	40	40	30	30	140	90	80	70	70	200	140	110	110	100
0.10	60	40	40	30	30	120	80	70	70	70	180	140	110	100	100
0.11	50	40	30	30	30	110	80	70	70	60	160	120	110	100	100
0.12	50	40	30	30	30	100	70	70	60	60	160	110	100	100	90
0.13	50	40	30	30	30	100	70	70	60	60	160	110	100	90	90
0.14	50	30	30	30	30	90	70	60	60	60	140	100	100	90	90
0.15	40	30	30	30	30	80	70	60	60	60	120	100	90	90	90
0.16	40	30	30	30	30	80	60	60	60	60	110	100	90	90	90
0.17	40	30	30	30	30	80	60	60	60	60	110	90	90	90	90
0.18	40	30	30	30	30	70	60	60	60	60	110	90	90	90	80
0.19	30	30	30	30	30	70	60	60	60	60	110	90	90	80	80
0.20	30	30	30	30	30	70	60	60	60	60	100	90	80	80	80
0.25 or greater	30	30	30	30	30	60	60	50	50	50	90	80	80	80	80

Notes:

1. **Determining S rating**
   $S = kt_e$ where k = 1.0 for unsprinklered *firecells* and 0.5 for sprinklered *firecell*s. Therefore in this table the t_e values are the same as the *S ratings* for unsprinklered *firecells*.
2. **Interpretation**
   A_f = floor area of *firecell* (m²)
   A_v = area of vertical openings in *external walls* of the *firecell* (m²)
   A_h = area of horizontal openings in roof of *firecell* (m²)
   Linear interpolation is permitted where values of A_v/A_f or A_h/A_f lie between those given in the table.
3. **Location of openings**
   Openings to allow *fire* venting should be located in the most practicable manner to provide effective cross-ventilation. This reduces structural *fire* severity and facilitates *fire* fighting operations.
4. **Effective openings**
   a) Only those areas of *external walls* and roofs which can dependably provide airflow to and from the *fire* shall be used in calculating A_v and A_h. Such areas include windows containing non-*fire* resistant glass and likely to break shortly after exposure to significant heat.
   b) An allowance can be made for air leakage through the *external wall* of the *building* envelope. The allowance for inclusion in A_v shall be no greater than 0.1% of the *external wall* area where the wall is lined internally, and 0.5% if unlined.
   c) Only roof venting which is specifically designed to open or melt rapidly in the event of *fire* shall be included in the area A_h.
   d) For single floor *buildings* or the top floor of multi-floor *buildings*, where the structural system supporting the roof is non-rated and directly exposed to the *fire* (i.e. no ceiling installed), A_h/A_f may be taken as 0.2.
5. **Areas not regarded as openings**
   For the purpose of calculating A_v it shall be assumed that doors in *external walls* are closed. Wall areas clad in sheet metal shall not be included in the area A_v.
6. **Intermediate floors**
   Where a *firecell* contains *intermediate floors*, separate calculations shall be made to determine t_e, first by taking A_f as the total floor area in the *firecell* (as defined in Paragraph 2.3.3), then by taking A_f separately as the floor area of each level. The highest value of t_e shall be used to determine the *S rating.*
7. **Background to table**
   Table 5.1 is derived using Equation E3 from Annex E, Eurocode DD ENV 1991-2-2: 1996, Eurocode 1: Basis of Design and Actions on Structures, Part 2.2 Actions on Structures Exposed to Fire (together with United Kingdom National Application Document); British Standards Institution, London, England. A *firecell* height of 3.0 m has been assumed and a thermal inertia factor corresponding to the most severe conditions (i.e. those which generate the highest t_e values and which correspond to use of k_b = 0.09 in Equation E3) for typical materials of *firecell construction*. For *firecells* which differ from these assumptions, especially with regard to the materials of *construction*, more accurate answers may be obtained with specific *fire* engineering design, which is mandatory for *fire hazard category* 4.

Appendix B

BCA C1.1 **Tables 3, 4, 5** **Fire-Resisting Construction**

From BCA 2007 - Volume One
Section C, Specification C1.1-3, Table 3
Type A Construction: FRL of Building Elements

Building Element	**Class of Building – FRL (in minutes)**			
	Structural Adequacy/Integrity/Insulation			
	2, 3 or 4 part	5, 7a or 9	6	7B or 8
EXTERNAL WALL (including any column and other building element incorporated therein) or other external building element, where the distance from any fire-source feature to which it is exposed is –				
For loadbearing parts				
< 1.5 m	90/90/90	120/120/120	180/180/180	240/240/240
1.5 – 3m	90/60/60	120/90/60	180/180/120	240/240/120
> 3m	90/60/30	120/60/30	180/120/90	240/180/90
For *non-loadbearing* parts				
< 1.5m	-/90/90	-/120/120	-/180/180	-/240/240
1.5 – 3m	-/60/60	-/90/90	-/180/120	-/240/180
> 3m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
EXTERNAL COLUMN not incorporated in an external wall, where the distance from any fire-source feature to where it is exposed is:				
< 3m	90/-/-	120/-/-	180/-/-	240/-/-
> 3m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
Common Walls and Fire Walls	90/90/90	120/120/120	180/180/180	240/240/240
INTERNAL WALLS				
Fire resisting lift and stair shafts				
Loadbearing	90/90/90	120/120/120	180/120/120	240/120/120
Non-LoadBearing	-/90/90	-/120/120	-/120/120	-/120/120
Bounding public corridors, public lobbies and the like				
LoadBearing	90/90/90	120/-/-	180/-/-	240/-/-
Non-LoadBearing	-/60/60	/-/-/-	/-/-/-	/-/-/-
Between or bounding sole-occupancy units				
LoadBearing	90/90/90	120/-/-	180/-/-	240/-/-
Non-LoadBearing	-/60/60	/-/-/-	/-/-/-	/-/-/-
Ventilation pipe, garbage and like shafts not used for the discharge of hot products of combustion				
LoadBearing	90/90/90	120/90/90	180/120/120	240/120/120
Non-LoadBearing	-/90/90	-/90/90	-/120/120	-/120/120
OTHER LOADBEARING INTERNAL WALLS and COLUMNS				
	90/-/-	120/-/-	180/-/-	240/-/-
Floors	90/90/90	120/120/120	180/180/180	240/240/240
Roofs	90/60/30	120/60/30	180/60/30	240/90/60

From BCA 2007 - Volume One
Section C, Specification C1.1-4
Type A Construction: FRL of Building Elements

remedial BUILDING SERVICES

Building Element	**Class of Building – FRL (in minutes)**			
	Structural Adequacy/Integrity/Insulation			
	2, 3 or 4 part	5, 7a or 9	6	7B or 8
EXTERNAL WALL (including any column and other building element incorporated therein) or other external building element, where the distance from any fire-source feature to which it is exposed is –				
For loadbearing parts				
< 1.5 m	90/90/90	120/120/120	180/180/180	240/240/240
1.5 – 3m	90/60/30	120/90/60	180/120/90	240/180/120
3 – 9 m	90/30/30	120/30/30	180/90/60	240/90/60
9 – 18m	90/30/-	120/30/-	180/60/-	240/60/-
> 18m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
For *non-loadbearing* parts				
< 1.5m	-/90/90	-/120/120	-/180/180	-/240/240
1.5 – 3m	-/60/30	-/90/60	-/120/90	-/180/120
> 3m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
EXTERNAL COLUMN not incorporated in an external wall, where the distance from any fire-source feature				
< 3m	90/-/-	120/-/-	180/-/-	240/-/-
> 3m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
COMMON WALLS and FIRE WALLS	90/90/90	120/120/120	180/180/180	240/240/240
INTERNAL WALLS				
Fire resisting lift and stair shafts				
Loadbearing	90/90/90	120/120/120	180/180/180	240/240/240
Fire resisting stair shafts				
Non-LoadBearing	-/90/90	-/120/120	-/180/180	-/240/240
Bounding public corridors, public lobbies and the like				
LoadBearing	60/60/60	120/-/-	180/-/-	240/-/-
Non-LoadBearing	-/60/60	/-/-/-	/-/-/-	/-/-/-
Between or bounding sole-occupancy units				
LoadBearing	60/60/60	120/-/-	180/-/-	240/-/-
Non-LoadBearing	-/60/60	/-/-/-	/-/-/-	/-/-/-
OTHER LOADBEARING INTERNAL WALLS and COLUMNS				
	60/-/-	120/-/-	180/-/-	240/-/-

From BCA 2007 - Volume One
Section C, Specification C1.1-5
Type C Construction: FRL of Building Elements

Building Element	**Class of Building – FRL (in minutes)**			
	Structural Adequacy/Integrity/Insulation			
	2, 3 or 4 part	5, 7a or 9	6	7B or 8
EXTERNAL WALL (including any column and other building element incorporated therein) or other external building element, where the distance from any fire-source feature to which it is exposed is –				
For loadbearing parts				
< 1.5 m	90/90/90	90/90/90	90/90/90	90/90/90
1.5 – 3m	/-/-/-	60/60/60	60/60/60	60/60/60
3m or more	/-/-/-	/-/-/-	/-/-/-	/-/-/-
EXTERNAL COLUMN not incorporated in an external wall, where the distance from any fire-source feature				
< 1.5m	90/-/-	90/-/-	90/-/-	90/-/-
1.5 – 3m	/-/-/-	60/-/-	60/-/-	60/-/-
> 3m	/-/-/-	/-/-/-	/-/-/-	/-/-/-
COMMON WALLS and FIRE WALLS	90/90/90	90/90/90	90/90/90	90/90/90
INTERNAL WALLS				
Bounding public corridors, public lobbies and the like				
	60/60/60	-/-/-	-/-/-	-/-/-
Between or bounding sole-occupancy units				
	60/60/60	-/-/-	-/-/-	-/-/-
Bounding a stair if required *to be rated*				
	60/60/60	60/60/60	60/60/60	60/60/60
OTHER LOADBEARING INTERNAL WALLS and COLUMNS				
	60/-/-	120/-/-	180/-/-	240/-/-
ROOFS	-/-/-	-/-/-	-/-/-	-/-/-

Appendix C

GIB® Fire Rated Floor/Ceiling Systems

Timber Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBFC 15	LB	15/15/15	1 layer 13mm GIB® Standard	38	31	40kg/m²

FLOOR FRAMING

Floor Joists must comply with NZS 3604 and be a minimum of 150 x 50mm spaced at 600mm maximum. Solid strutting is required at 1800mm centres.
Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.
Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600mm for joists at 600mm or at 1200mm for joists at 400 or 450mm.
Nogs/framing is required at the perimeter of the fire rated ceiling.

ALTERNATIVE FLOOR FRAMING

Hyspan® or Hybeam® HJ series joists[1] may be used as an alternative. Joists must be covered by specific engineering design for strength and serviceability and spaced at no more than 600 mm centres.
Requirements for nogs are the same as for NZS 3604 floor framing above.
Consult the beam manufacturer re construction of the solid blocking contained in floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

1 layer 13mm GIB® Standard Plasterboard shall be fixed at right angles to the underside of the floor joists.
All joints must occur on joists, solid strutting or nogs.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners
32mm x 6g GIB® Grabber® High Thread Drywall Screws.
Fastener Centres
150mm centres around the perimeter of each sheet.
Single screws at 200mm centres along each joist and at the centre of each nog.
Place fasteners 12mm from sheet edges.

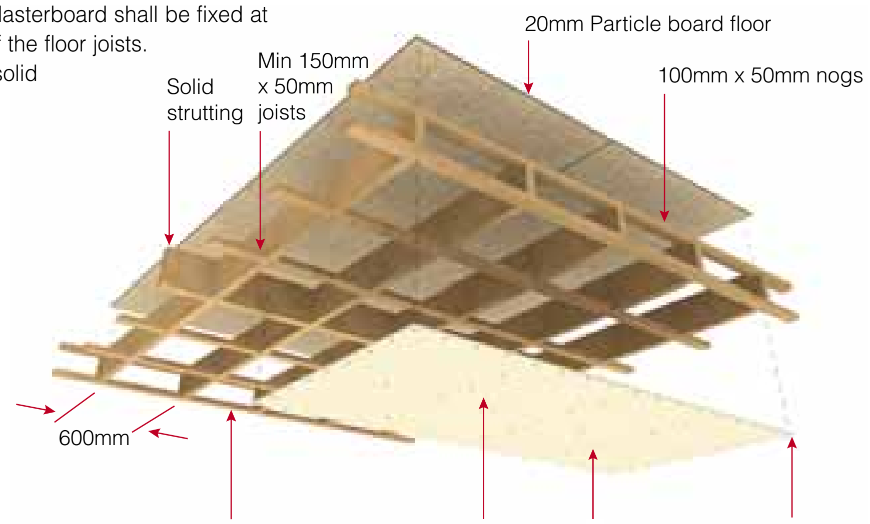
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

[1] Hyspan® or Hybeam® HJ series joists are manufactured and supplied by Carter Holt Harvey Futurebuild, 0800 808 131. The following alternatives are available. Please check with the supplier for construction details and independent verification.
- Posi Strut® joists – Mitek Group, (09) 274 7109
- Twinaplate® joists – Twinaplate® NZ, (09) 813 4007



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Timber Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBFC 45	LB	45/45/45	1 layer 13mm GIB Fyreline®	39	32	44kg/m²

FLOOR FRAMING

Floor Joists must comply with NZS 3604 and be a minimum of 200 x 50mm spaced at 600mm maximum. Solid strutting is required at 1800mm centres.
Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.
Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600mm for joists at 600mm or at 1200mm for joists at 400 or 450mm.
Nogs/framing is required at the perimeter of the fire rated ceiling.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

1 layer of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the floor joists.
All joints must occur on joists, solid strutting or nogs.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners
51mm x 7g GIB® Grabber® High Thread Drywall Screws.
Fastener Centres
150mm centres around the perimeter of each sheet.
Single screws at 200mm centres along each joist and at the centre of each nog.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

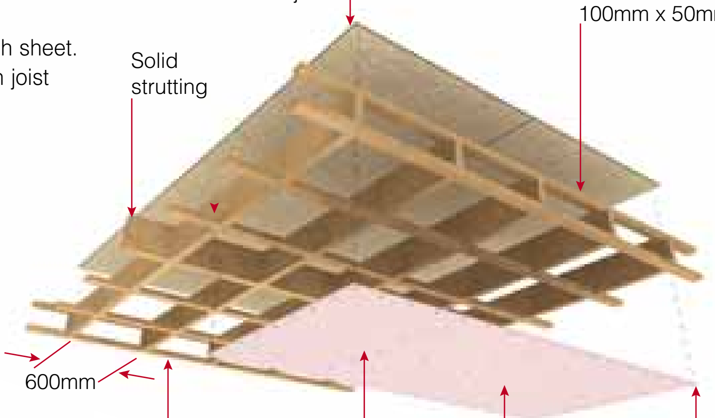
The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

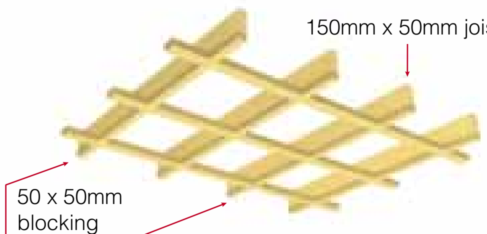
All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

CEILING BATTEN ALTERNATIVE

Where NZS 3604 permits 150mm joists, these may be used with continuous 75 x 50mm ceiling battens at 600mm centres, running across the joists (battens may also be used to level the ceiling in renovation work).
When joists are spaced at 600mm, 50 x 50mm blocking between the ceiling battens is required under all joists. When joists are spaced at 400mm, blocking on joists is required behind lining joints at 1200mm centres only.
When joists are at 450mm, nogs are required between the battens at 600mm centres (or at 1200mm centres when battens are spaced at 450mm or less). Nogs/framing is required at the perimeter of the fire rated ceiling.
The lining shall be fixed at right angles to the underside of the battens.



Ceiling Batten Alternative



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Composite Joists

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBCJ 45	LB	45/45/45	1 layer 13mm GIB Fyreline®	39	32	40kg/m²

FLOOR FRAMING

Floor joists may be either Hyspan® or Hybeam® HJ series joists[1].

Joists shall be covered by specific engineering design for strength and serviceability, have a depth no less than 200mm and spacing no more than 600mm.

Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.

Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600mm for joists at 600mm, or at 1200mm for joists at 400 or 450mm.

Nogs/framing is required at the perimeter of the fire rated ceiling.

Consult the beam manufacturer re construction of the solid blocking contained in floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

1 layer of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the floor joists.

All joints must occur on joists or nogs.

Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners

51mm x 7g GIB® Grabber® High Thread Drywall Screws.

Fastener Centres

150mm centres around the perimeter of each sheet.

Single screws at 200mm centres along each joist and at the centre of each nog.

Place fasteners 12mm from sheet edges.

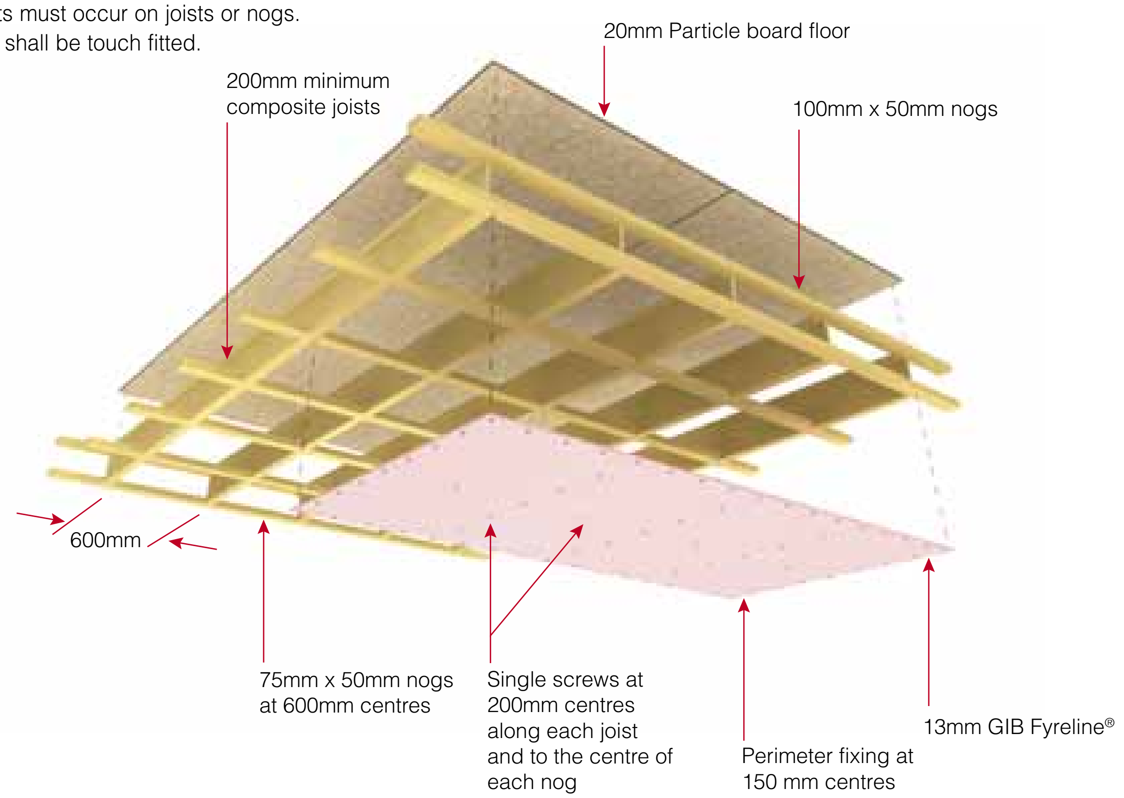
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

[1] Hyspan® or Hybeam® HJ series joists are manufactured and supplied by Carter Holt Harvey Futurebuild, 0800 808 131. The following alternatives are available. Please check with the supplier for construction details and independent verification.
- Posi Strut® joists – Mitek Group, (09) 274 7109
- Twinaplate® joists – Twinaplate® NZ, (09) 813 4007



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Timber Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBFC 60	LB	60/60/60	1 layer 16mm GIB Fyreline®	39	32	46kg/m^2

FLOOR FRAMING

Floor Joists must comply with NZS 3604 and be a minimum of 200 x 50mm spaced at 600mm maximum. Solid strutting is required at 1800mm centres.
Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.
Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600mm for joists at 600mm or at 1200mm for joists at 400 or 450mm.
Nogs/framing is required at the perimeter of the fire rated ceiling.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

1 layer of 16mm GIB Fyreline® shall be fixed at right angles to the underside of the floor joists.
All joints must occur on joists, solid strutting or nogs.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners
51mm x 7g GIB® Grabber® High Thread Drywall Screws.
Fastener Centres
150mm centres around the perimeter of each sheet.
Single screws at 200mm centres along each joist and at the centre of each nog.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

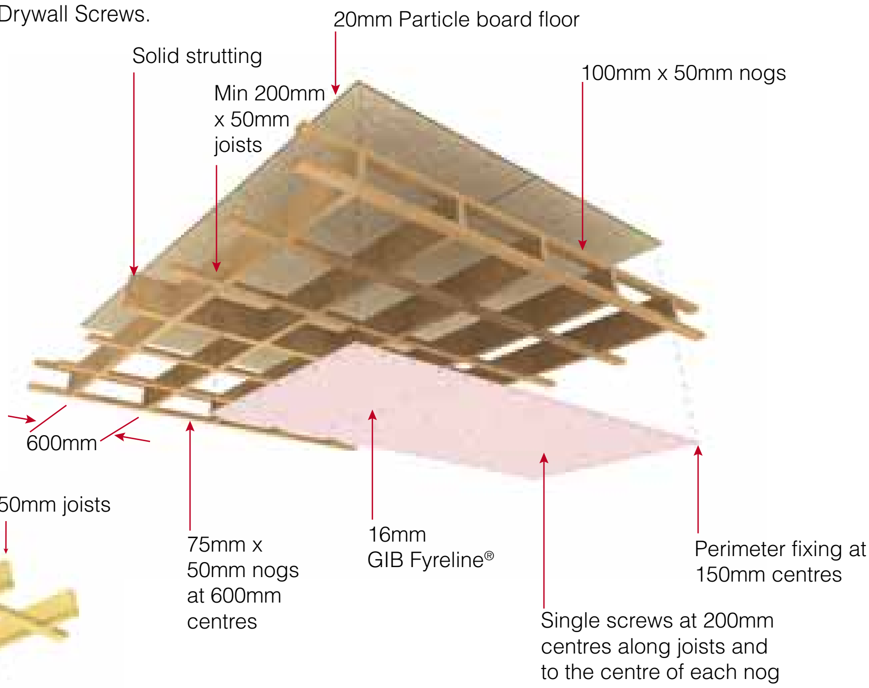
The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

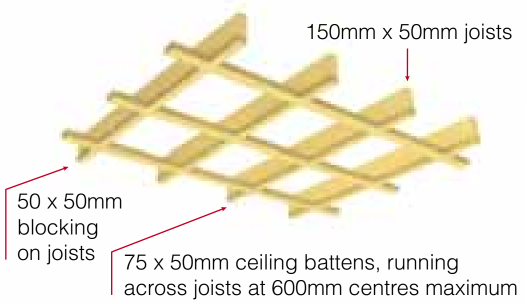
All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

CEILING BATTEN ALTERNATIVE

Where NZS 3604 permits 150mm joists, these may be used with continuous 75 x 50mm ceiling battens at 600mm centres, running across the joists (battens may also be used to level the ceiling in renovation work).
When joists are spaced at 600mm, 50 x 50mm blocking between the ceiling battens is required under all joists.
When joists are spaced at 400mm, blocking on joists is required behind lining joints at 1200mm centres only.
When joists are at 450mm, nogs are required **between the battens** at 600mm centres (or at 1200mm centres when battens are spaced at 450mm or less)
Nogs/framing is required at the perimeter of the fire rated ceiling.
The lining shall be fixed at right angles to the underside of the battens.



Ceiling Batten Alternative



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Composite Joists

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBCJ 60	LB	60/60/60	1 layer 16mm GIB Fyreline®	39	32	44kg/m²

FLOOR FRAMING

Floor joists may be either Hyspan® or Hybeam® HJ series joists[1].
Joists shall be covered by specific engineering design for strength and serviceability, have a depth no less than 200mm and spacing no more than 600mm.
Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.
Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600mm for joists at 600mm, or at 1200mm for joists at 400 or 450mm.
Nogs/framing is required at the perimeter of the fire rated ceiling.
Consult the beam manufacturer re construction of the solid blocking contained in floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

1 layer of 16mm GIB Fyreline® shall be fixed at right angles to the underside of the floor joists.
All joints must occur on joists or nogs.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners
51mm x 7g GIB® Grabber® High Thread Drywall Screws.
Fastener Centres
150mm centres around the perimeter of each sheet.
Single screws at 200mm centres along each joist and at the centre of each nog.
Place fasteners 12mm from sheet edges.

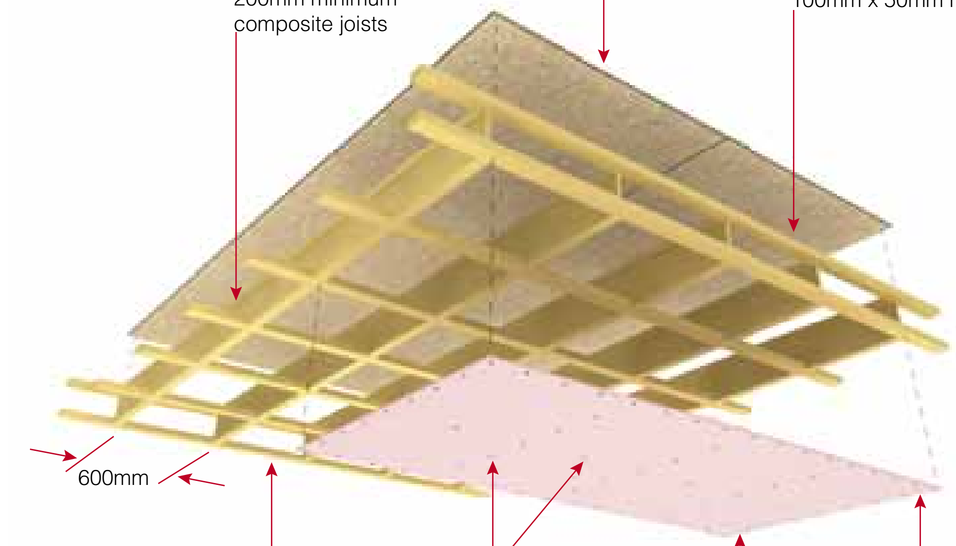
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

[1] Hyspan® or Hybeam® HJ series joists are manufactured and supplied by Carter Holt Harvey Futurebuild, 0800 808 131. The following alternatives are available. Please check with the supplier for construction details and independent verification.
- Posi Strut® joists – Mitek Group, (09) 274 7109
- Twinaplate® joists – Twinaplate® NZ, (09) 813 4007



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Timber Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBFC 90	LB	90/90/90	2 layers 16mm GIB Fyreline®	41	34	63kg/m²

FLOOR FRAMING

Floor Joists must comply with NZS 3604 and be a minimum of 200 x 50mm spaced at 400mm maximum. Solid strutting is required at 1800mm centres.
Nogs fixed on the flat to receive the ends of flooring material shall be 100 x 50mm minimum.
Nogs fixed on the flat to receive GIB® linings shall be 75 x 50mm minimum spaced at 600 centres.
Nogs/framing is required at the perimeter of the fire rated ceiling.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

2 layers of 16mm GIB Fyreline® shall be fixed at right angles to the underside of the floor joists.
The joints of the second layer are to be offset 600mm from those of the first layer.
All joints must occur on joists, solid strutting or nogs.
Sheets shall be touch fitted.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

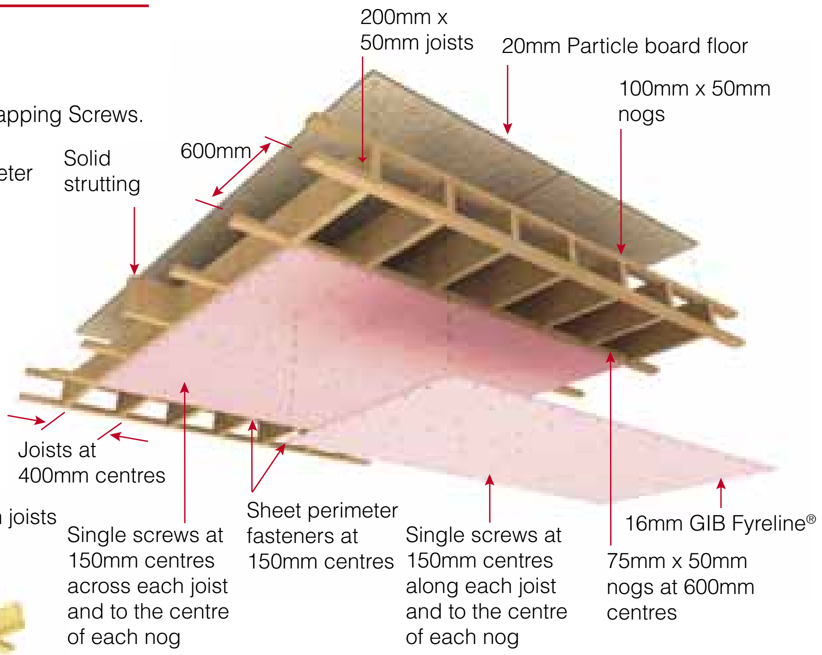
CEILING BATTEN ALTERNATIVE

Where NZS 3604 permits 150mm joists, these may be used with continuous 75 x 50mm ceiling battens at 600mm centres, running across the joists (battens may also be used to level the ceiling in renovation work).
50 x 50mm blocking between the ceiling battens is required under all joists.
Nogs/framing is required at the perimeter of the fire rated ceiling.
The lining shall be fixed at right angles to the underside of the battens.
The joints of the outer layer are to be offset **400mm** from those of the inner layer.

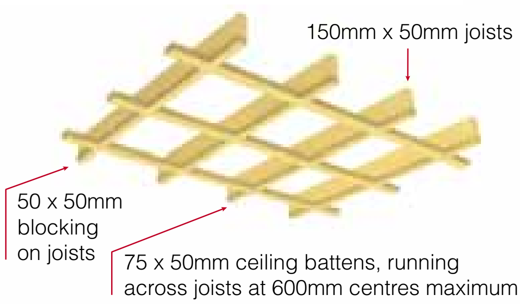
FASTENING THE LINING

Fasteners
INNER LAYER: 51mm x 7g GIB® Grabber® High Thread Drywall Screws.
OUTER LAYER: 76mm x 8g GIB® Grabber® Self Tapping Screws.

Fastener Centres
INNER LAYER: 150mm centres around the perimeter of each sheet and across each joist and at the centre of each nog.
OUTER LAYER: 150mm centres around the perimeter of each sheet and single screws at 200mm centres along each joist and at the centre of each nog.
Place fasteners 12mm from sheet edges.



Ceiling Batten Alternative



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Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBFC 120	LB	120/120/120	2 layers 19mm GIB Fyreline®

FLOOR FRAMING

Timber or steel floor joists designed to meet structural criteria for strength and serviceability under dead and live loads.
Joists at 500mm centres maximum.
The separation distance between the ceiling lining and the flooring shall be 90mm minimum.
Linings shall be supported by framing members with a minimum width of 35mm.
Nogs fixed on the flat to receive the ends of the particle board shall be 100mm x 50mm minimum.

Note: *In respect of the FRR for this particular system, nogs are required only at the perimeter of the fire rated ceiling. If timber framed construction applies, the nogs shall be 75 x 40mm minimum.*

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.

Note: *If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.*

CEILING LINING

2 layers of 19mm GIB Fyreline® shall be fixed at right angles to the underside of the floor framing.
The joints of the second layer are to be offset 600mm from those of the first layer.
Sheets shall be touch fitted.
All sheet end butt joints must occur over solid framing.

FASTENING THE LINING

Fasteners

LAYER	TIMBER FRAME	STEEL FRAME
Inner layer	41mm x 6g GIB® Grabber® High Thread Drywall Screws	41mm x 6g GIB® Grabber® Self Tapping Screws
Outer layer	63mm x 8g GIB® Grabber® Self Tapping Screws	51 x 7g screws as above

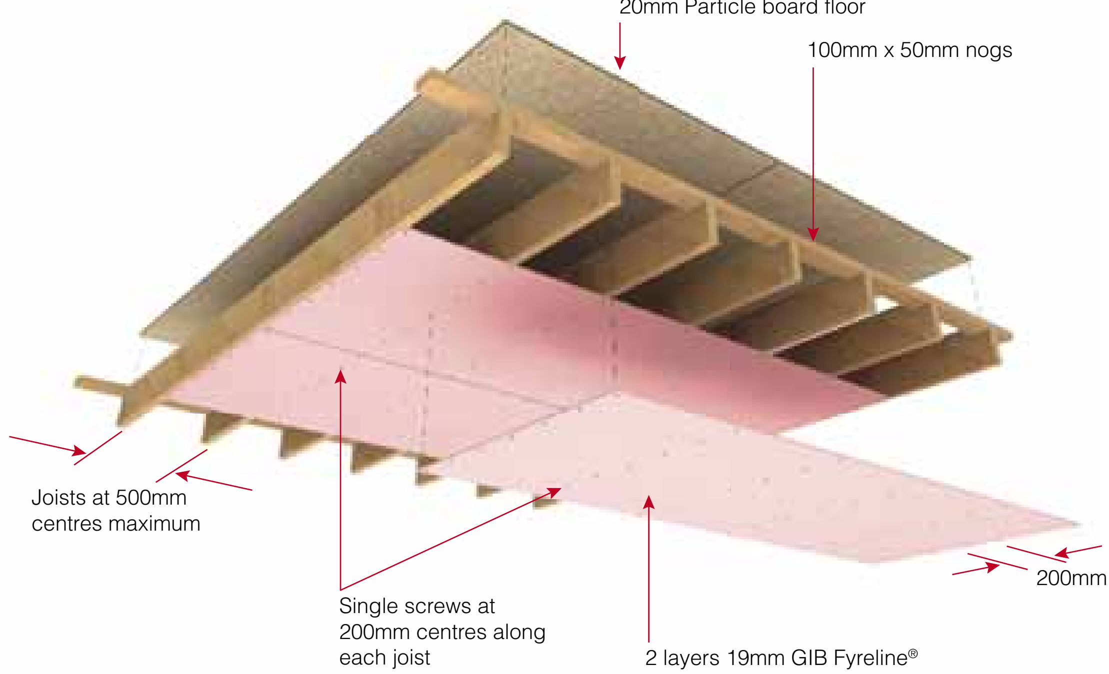
Fastener Centres (both layers)
At 200mm centres around the ceiling perimeter, along each framing member, and at 200mm centres to framing members where sheet end butt joints occur.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Suspended Grid

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBSC 30	LB	30/30/30	1 layer 13mm GIB Fyreline®	48	43	50kg/m²

FLOOR FRAMING

Timber floor joists complying with NZS 3604 spaced at 600mm centres maximum.
Alternatively, a proprietary I-joist system may be used subject to specific structural design and approval by the normal building consent process.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.
Note: If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG Donn® ScrewFix™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting DJ 38 strongback channels spaced at 1200mm centres and FC37 furring channels spaced at 600mm centres maximum.
Rondo® Key-Lock™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting top cross rails (part 128) spaced at 1200mm centres and furring channels (part 129) spaced at 600mm centres maximum.
An alternative suspension system with at least equivalent layout, material properties, strength and stiffness may be used.

CEILING LINING

1 layer of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the furring channels.
All sheet end butt joints must occur on the furring channels.
Sheets shall be touch fitted.
Joints formed by sheet edges shall be back blocked between the furring channels with strips of 13mm GIB Fyreline®.
The width of the back blocks shall be 300mm minimum and shall be adhered with GIB-Cove® Bond.

FASTENING THE LINING

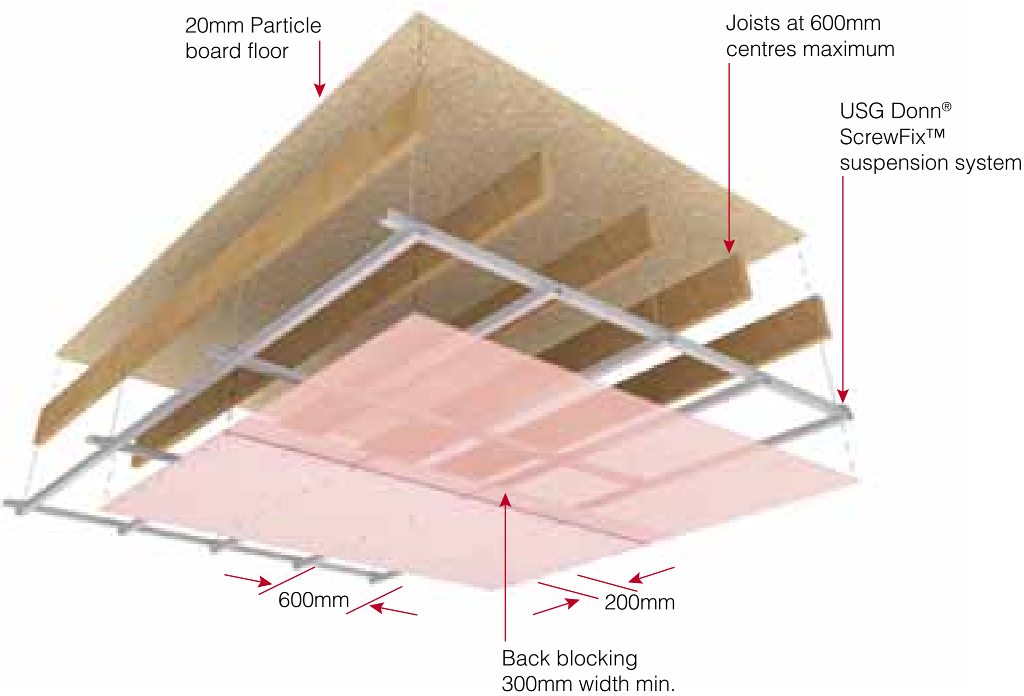
Fasteners
25mm x 6g GIB® Grabber® Drywall Self Tapping Screws.
Fastener Centres
200mm centres along each intermediate furring channel, around the ceiling perimeter and where sheet end butt joints occur.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".



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GIB

Suspended Grid

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBSC 60a	LB	60/60/60	2 layers 13mm GIB Fyreline®	53	43	60kg/m²

FLOOR FRAMING

Timber floor joists complying with NZS 3604 spaced at 600mm centres maximum.
Alternatively, a proprietary I-joist system may be used subject to specific structural design and approval by the normal building consent process.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturers' specifications.
Note: If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG Donn® ScrewFix™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting DJ38 strongback channels spaced at 1200mm centres and FC37 furring channels spaced at 600mm centres maximum.
Rondo® Key-Lock™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting top cross rails (part 128) spaced at 1200mm centres and furring channels (part 129) spaced at 600mm centres maximum.
An alternative suspension system with at least equivalent layout, material properties, strength and stiffness may be used.

CEILING LINING

2 layers of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the furring channels.
The joints of the second layer are to be offset 600mm from those of the first layer.
All sheet end butt joints must occur on the furring channels.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners

INNER LAYER: 25mm x 6g GIB® Grabber® Drywall Self Tapping Screws.

OUTER LAYER: 41mm x 6g screws as above.

Fastener Centres

200mm centres along intermediate furring channel, around the ceiling perimeter and where sheet end butt joints occur.
Place fasteners 12mm from sheet edges.

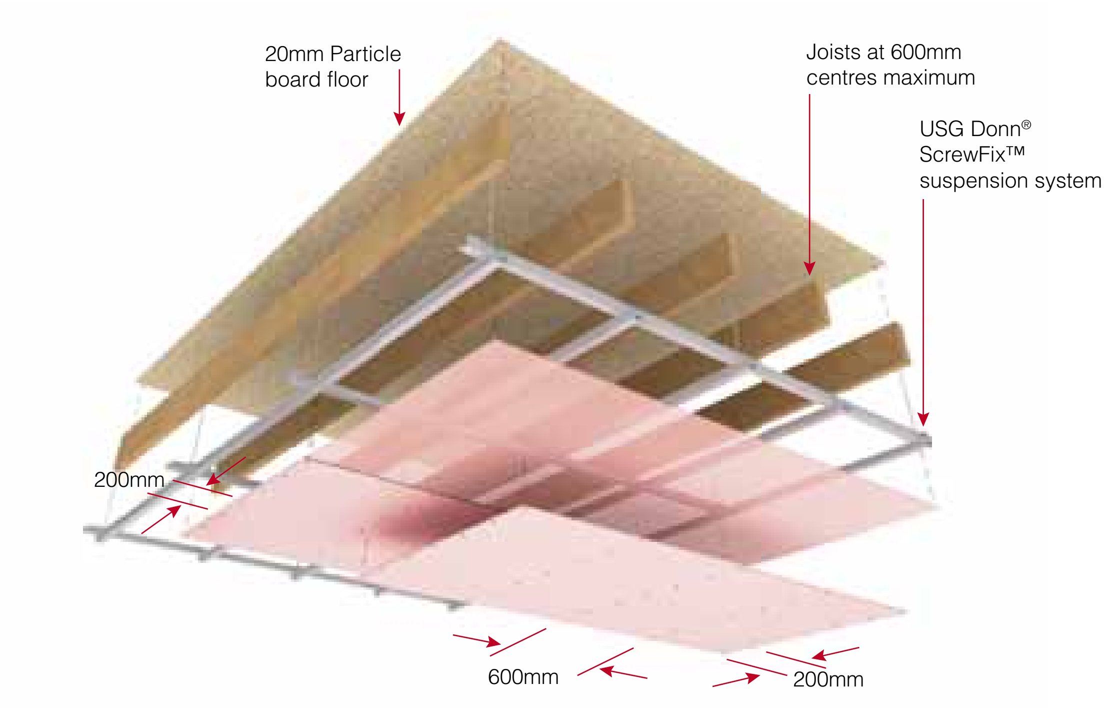
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

INNER LAYER: Unstopped

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".



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FIRE RATED FLOOR/CEILING SYSTEMS – SECTION 3.2

Suspended Grid

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBSC 60b	LB	60/60/60	1 layer 16mm GIB Fyreline®	50	43	54kg/m²

FLOOR FRAMING

Timber floor joists complying with NZS 3604 spaced at 600mm centres maximum.
Alternatively, a proprietary I-joist system may be used subject to specific structural design and approval by the normal building consent process.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 18mm thick structural plywood fixed to joists in accordance with the manufacturers specifications.
Note: If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG Drywall Grid Suspension System comprising 2.5mm wire hangers or DJ4040 wall angles at 1200mm centres maximum. Hangers support DGL40D main tee at 1200mm centres maximum. DGW40D-1200 cross tees installed at 600mm centres. DGW40D-600 cross tees installed at 1200mm centres, parallel with the main tee.
The distance between the underside of the flooring and the top of the ceiling linings shall be a minimum of 450mm.

Note: *Suspension system must be installed in accordance with manufacturer's specification.*

CEILING LINING

1 layer of 16mm GIB Fyreline® shall be fixed parallel to the main tees and positioned so tapered edges are located on DGW40D-600 cross tees.
All sheet end butt joints must occur on the suspension system.
Sheets shall be touch fitted.

FASTENING THE LINING

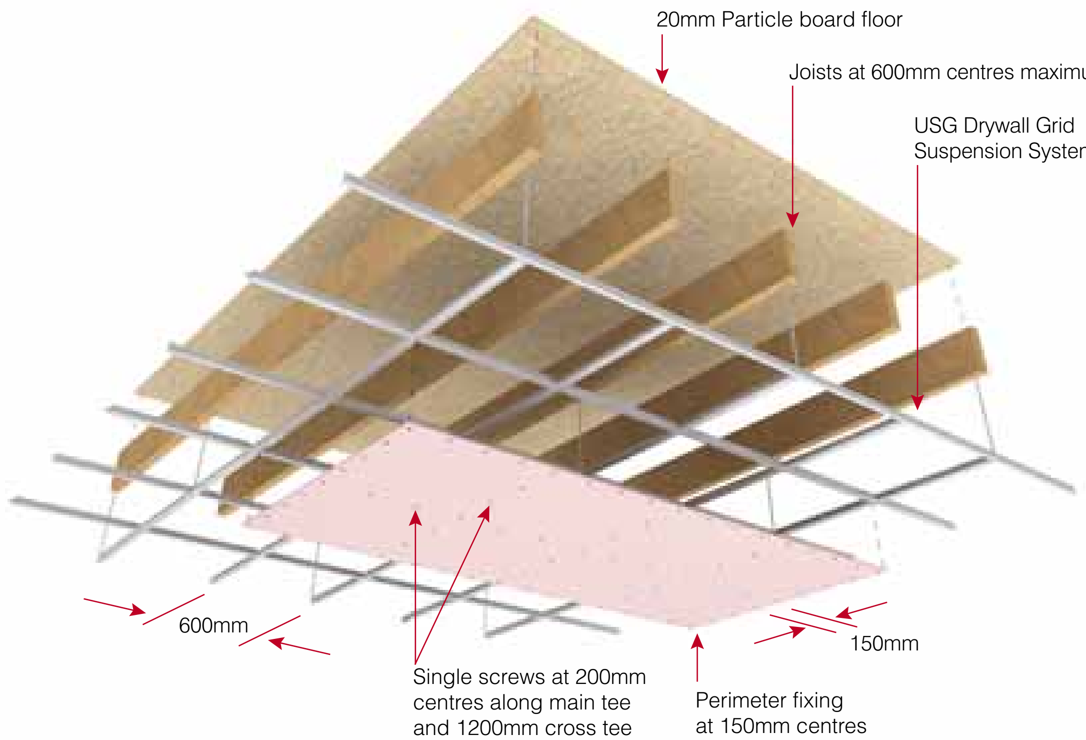
Fasteners
32mm x 6g GIB® Grabber® Drywall Self Tapping Screws.
Fastener Centres
150mm centres around the perimeter of each sheet.
Single screws at 200mm centres along each DGL40D main tee and DGW40D-1200 cross tee.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".



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FIRE RATED FLOOR/CEILING SYSTEMS – SECTION 3.2

Suspended Grid

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS	STC	IIC	SYSTEM WEIGHT APPROX
GBSC 90	LB	90/90/90	1 layer 13mm GIB Fyreline® + 1 layer of 16mm GIB Fyreline®	53	43	64kg/m²

FLOOR FRAMING

Timber floor joists complying with NZS 3604 spaced at 600mm centres maximum.
Alternatively, a proprietary I-joist system may be used subject to specific structural design and approval by the normal building consent process.

FLOORING

Minimum flooring shall be nominal 20mm thick particle board or minimum 18mm thick structural plywood fixed to joists in accordance with the manufacturers specifications.
Note: If tongue and groove sheet flooring is used, verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG Drywall Grid Suspension System comprising 2.5mm wire hangers or DJ4040 wall angles at 1200mm centres maximum. Hangers support DGW55D main tee at 1200mm centres maximum. DGW40D-1200 cross tees installed at 600mm centres.
The distance between the underside of the flooring and the top of the ceiling linings shall be a minimum of 450mm.

Note 1: *Additional DGW40D-1200 cross tees are required 200mm both sides of sheet end butt joints.*

Note 2: *Suspension system must be installed in accordance with manufacturer's specification.*

JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

CEILING LINING

1 layer of 13mm GIB Fyreline® shall be fixed parallel to the DGL55D main tees and positioned so tapered edges are located on the main tee. Sheet end butt joints must occur on DGW40D-1200 cross tees.
One layer of 16mm GIB Fyreline® shall be fixed parallel to main tees but offset by 600mm in both directions. Sheet end butt joints must occur on DGW40D-1200 cross tees.
Sheets shall be touch fitted.

FASTENING THE LINING

Fasteners

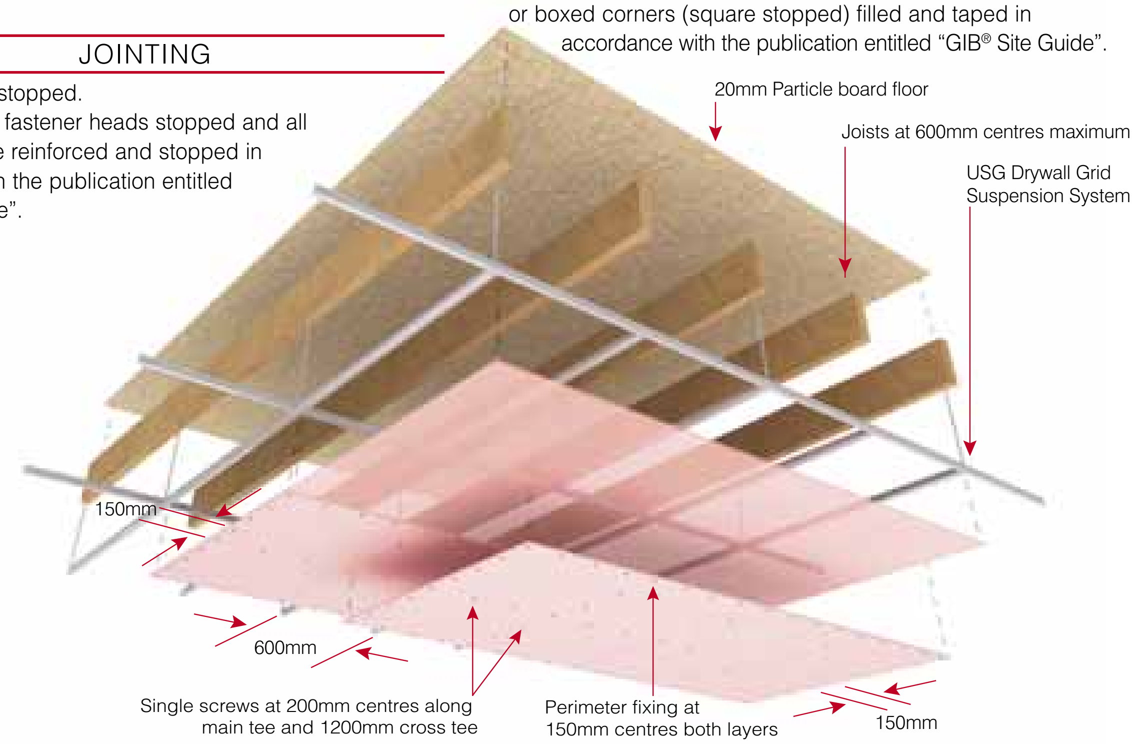
INNER LAYER: 25mm x 6g GIB® Grabber® Drywall Self Tapping Screws.
OUTER LAYER: 41mm x 6g and 38mm x 10g Laminator screws as above.

Fastener Centres

INNER LAYER: 150mm centres around perimeter of each sheet. Single screws at 200mm centres along each DGW40D-1200 cross tee.
OUTER LAYER: As above. Where sheet perimeter fasteners do not coincide with steel suspension component, GIB® Grabber® Laminator screws are to be used.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".



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Universal Ceilings – Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBUC 15	LB/NLB	(15)/15/15	1 layer 13mm GIB Fyreline®

FRAMING

Timber or steel roof or floor/ceiling framing designed to meet structural criteria for strength and serviceability under dead and live loads.
The separation distance between the ceiling linings and any flooring or roofing material shall be 90mm minimum.
Linings shall be supported by framing members with a minimum width of 35mm spaced at 600mm centres maximum.
Solid nogs shall be provided at 1200mm centres maximum and to the perimeter of the fire rated ceilings.
If timber framed construction applies, the nogs shall be 75 x 40mm minimum.

CEILING LINING

One layer of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the framing members.
Sheets shall be touch fitted.
All sheet joints must occur over solid framing.

FASTENING THE LINING

Fasteners

TIMBER FRAME	STEEL FRAME
41mm x 6g GIB® Grabber® High Thread Drywall Screws	25mm x 6g GIB® Grabber® Drywall Self Tapping Screws

Fastener Centres

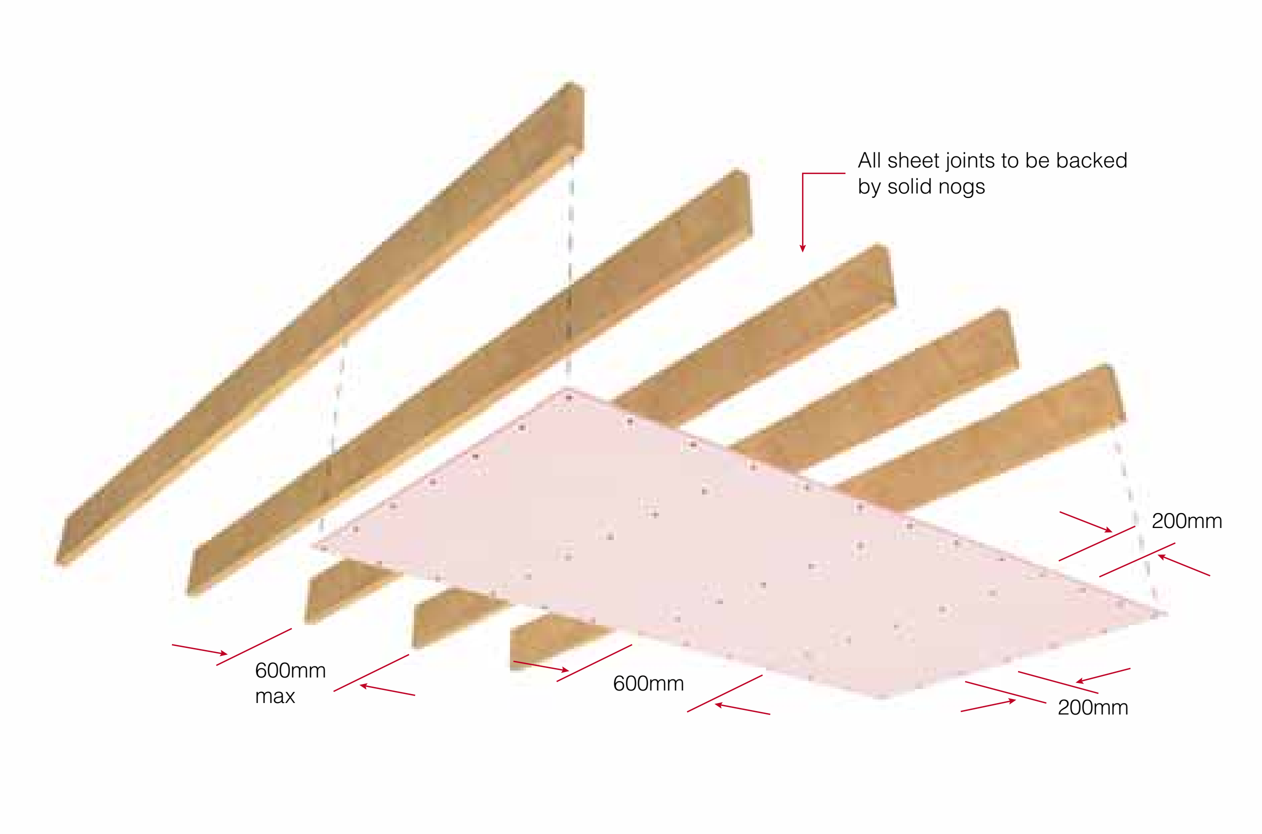
200mm centres around the sheet perimeters, along each intermediate framing member and at 200mm centres where sheet end butt joints occur.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled “GIB® Site Guide”.

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled “GIB® Site Guide”.



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Timber or Steel Frame
(30)/30/30
LB/NLB

Universal Ceilings – Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBUC 30	LB/NLB	(30)/30/30	1 layer 16mm GIB Fyreline®

FRAMING

Timber or steel roof or floor/ceiling framing designed to meet structural criteria for strength and serviceability under dead and live loads.
The separation distance between the ceiling linings and any flooring or roofing material shall be 90mm minimum.
Linings shall be supported by framing members with a minimum width of 35mm spaced at 600mm centres maximum.
Solid nogs shall be provided at 1200mm centres maximum and to the perimeter of the fire rated ceiling.
If timber framed construction applies, the nogs shall be 75 x 40mm minimum.

CEILING LINING

One layer of 16mm GIB Fyreline® shall be fixed at right angles to the underside of the framing members.
Sheets shall be touch fitted.
All sheet joints must occur over solid framing.

FASTENING THE LINING

Fasteners

TIMBER FRAME	STEEL FRAME
41mm x 6g GIB® Grabber® High Thread Drywall Screws	25mm x 6g GIB® Grabber® Drywall Self Tapping Screws

Fastener Centres

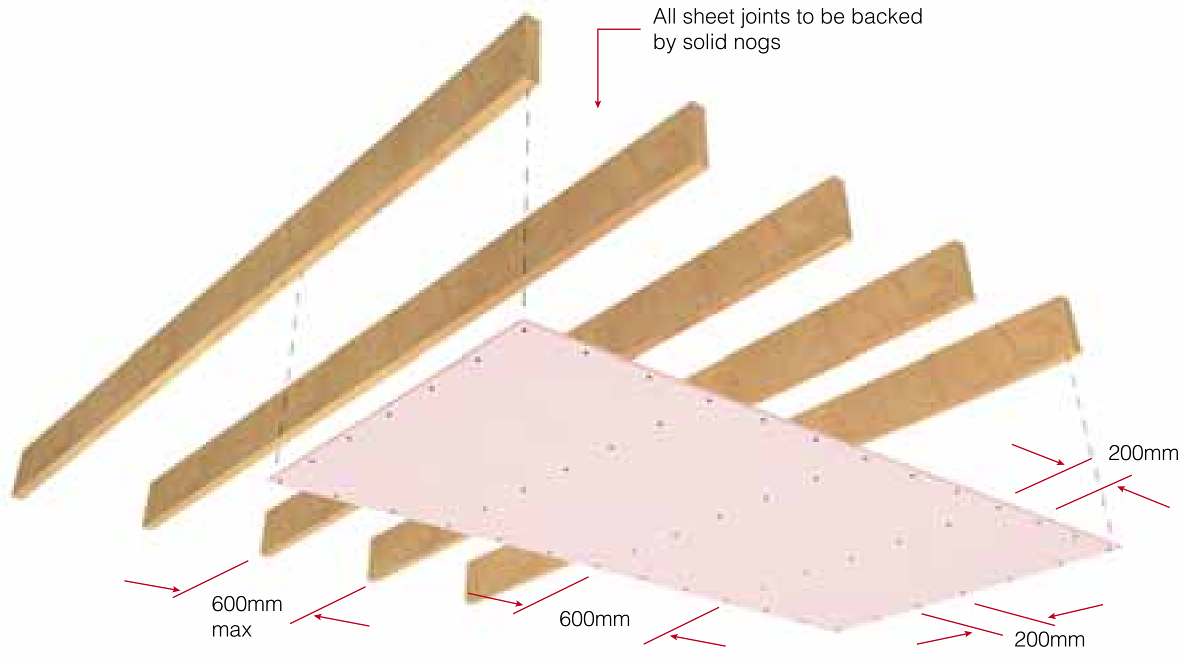
200mm centres around the sheet perimeters, along each intermediate framing member and at 200mm centres where sheet end butt joints occur.
Place fasteners 12mm from sheet edges.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled “GIB® Site Guide”.

JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled “GIB® Site Guide”.



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Universal Ceilings – Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBUC 45	LB/NLB	(45)/45/45	2 layers 13mm GIB Fyreline®

FRAMING

Timber or steel roof or floor/ceiling framing designed to meet structural criteria for strength and serviceability under dead and live loads.

The separation distance between the ceiling linings and any flooring or roofing material shall be 90mm minimum.

Linings shall be supported by framing members with a minimum width of 35mm spaced at 600mm centres maximum.

In respect of the FRR for this particular system, nogs are required only at the perimeter of the fire rated ceiling.

If timber framed construction applies, the nogs shall be 75 x 40mm minimum.

CEILING LINING

2 layers of 13mm GIB Fyreline® shall be fixed at right angles to the underside of the framing members.

The joints of the second layer are offset 600mm from those in the first layer.

Sheets shall be touch fitted.

All sheet end butt joints must occur over solid framing.

FASTENING THE LINING

Fasteners

LAYER	TIMBER FRAME	STEEL FRAME
Inner layer	41mm x 6g GIB® Grabber® High Thread Drywall Screws	25mm x 6g GIB® Grabber® Drywall Self Tapping Screws
Outer layer	51mm x 7g screws as above	41mm x 6g screws as above

Fastener Centres (both layers)

200mm centres around the ceiling perimeter, along each intermediate framing member and at 200mm centres where sheet end butt joints occur.

Place fasteners 12mm from sheet edges.

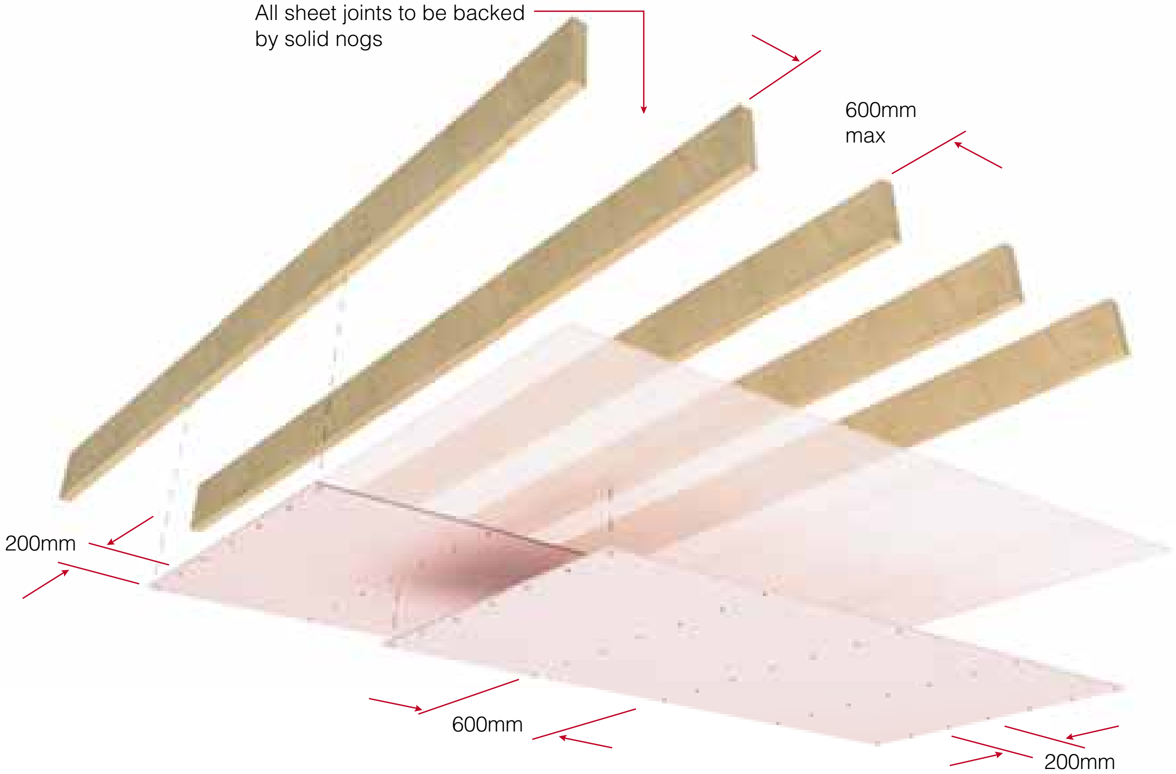
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled “GIB® Site Guide”.

JOINTING

INNER LAYER: Unstopped.

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled “GIB® Site Guide”.



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Universal Ceilings – Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBUC 60	LB/NLB	(60)/60/60	1 layer 16mm GIB Fyreline® + 1 layer 13mm GIB Fyreline®

FRAMING

Timber or steel roof or floor/ceiling framing designed to meet structural criteria for strength and serviceability under dead and live loads.

The separation distance between the ceiling linings and any flooring or roofing material shall be 90mm minimum.

Linings shall be supported by framing members with a minimum width of 35mm spaced at 600mm centres maximum.

In respect of the FRR for this particular system, nogs are required only at the perimeter of the fire rated ceiling.

If timber framed construction applies, the nogs shall be 75 x 40mm minimum.

CEILING LINING

1 layer of 16mm GIB Fyreline® (Inner layer) plus 1 layer of 13mm GIB Fyreline® fixed at right angles to the underside of the framing members.

The joints of the second layer are offset 600mm from those in the first layer.

Sheets shall be touch fitted.

All sheet end butt joints must occur over solid framing.

FASTENING THE LINING

Fasteners

LAYER	TIMBER FRAME	STEEL FRAME
Inner layer (16mm GIB Fyreline®)	41mm x 6g GIB® Grabber® High Thread Drywall Screws	25mm x 6g GIB® Grabber® Drywall Self Tapping Screws
Outer layer (13mm GIB Fyreline®)	51mm x 7g screws as above	41mm x 6g screws as above

Fastener Centres (both layers)

200mm centres around the ceiling perimeter, along each intermediate framing member and at 200mm centres where sheet end butt joints occur.

Place fasteners 12mm from sheet edges.

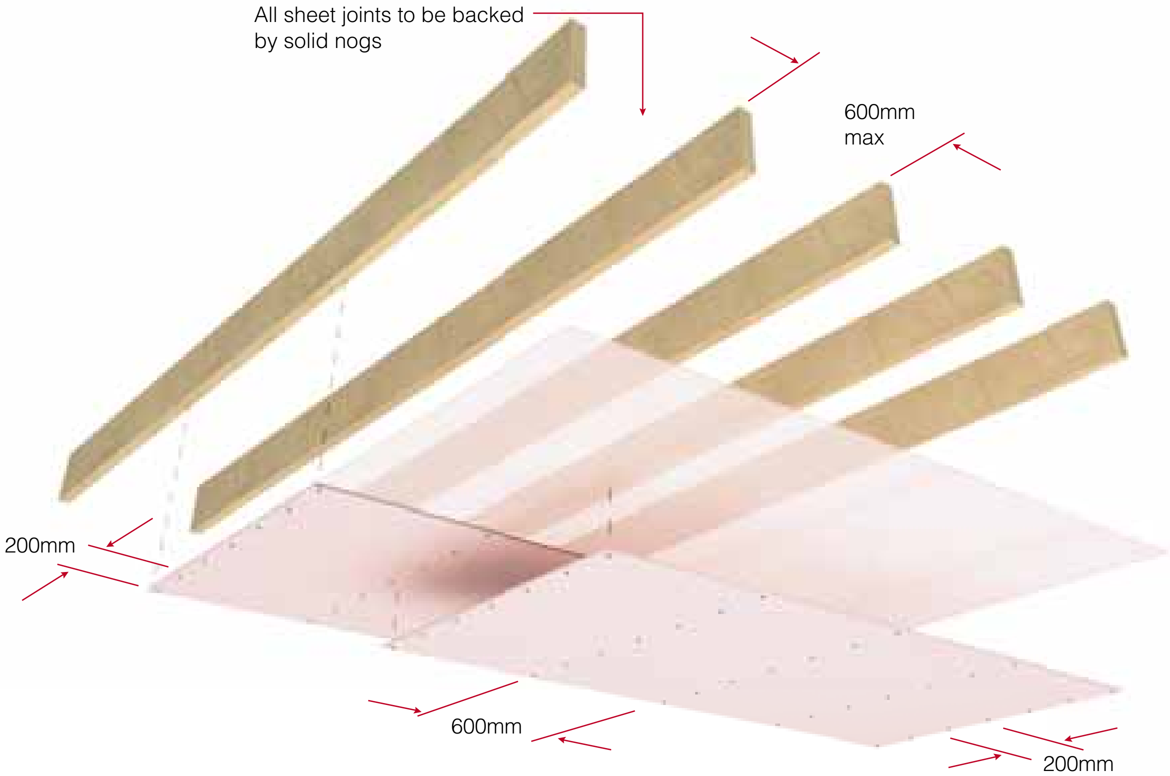
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled “GIB® Site Guide”.

JOINTING

INNER LAYER: Unstopped.

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled “GIB® Site Guide”.



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Universal Ceilings – Timber or Steel Frame

JANUARY 2006

SPECIFICATION NUMBER	LOADBEARING CAPACITY	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBUC 90	LB/NLB	(90)/90/90	2 layers 19mm GIB Fyreline®

FRAMING

Timber or steel roof or floor/ceiling framing designed to meet structural criteria for strength and serviceability under dead and live loads.

The separation distance between the ceiling linings and any flooring or roofing material shall be 90mm minimum.

Linings shall be supported by framing members with a minimum width of 35mm spaced at 600mm centres maximum.

In respect of the FRR for this particular system, nogs are required only at the perimeter of the fire rated ceiling. If timber framed construction applies, the nogs shall be 75 x 40mm minimum.

CEILING LINING

2 layers of 19mm GIB Fyreline® shall be fixed at right angles to the underside of the framing members.

The joints of the second layer are offset 600mm from those in the first layer.

Sheets shall be touch fitted.

All sheet end butt joints must occur over solid framing.

FASTENING THE LINING

Fasteners

LAYER	TIMBER FRAME	STEEL FRAME
Inner layer	41mm x 6g GIB® Grabber® High Thread Drywall Screws	32mm x 6g GIB® Grabber® Drywall Self Tapping Screws
Outer layer	51mm x 7g screws as above	51mm x 7g screws as above

Fastener Centres (both layers)

200mm centres around the ceiling perimeter, along each intermediate framing member and at 200mm centres where sheet end butt joints occur.

Place fasteners 12mm from sheet edges.

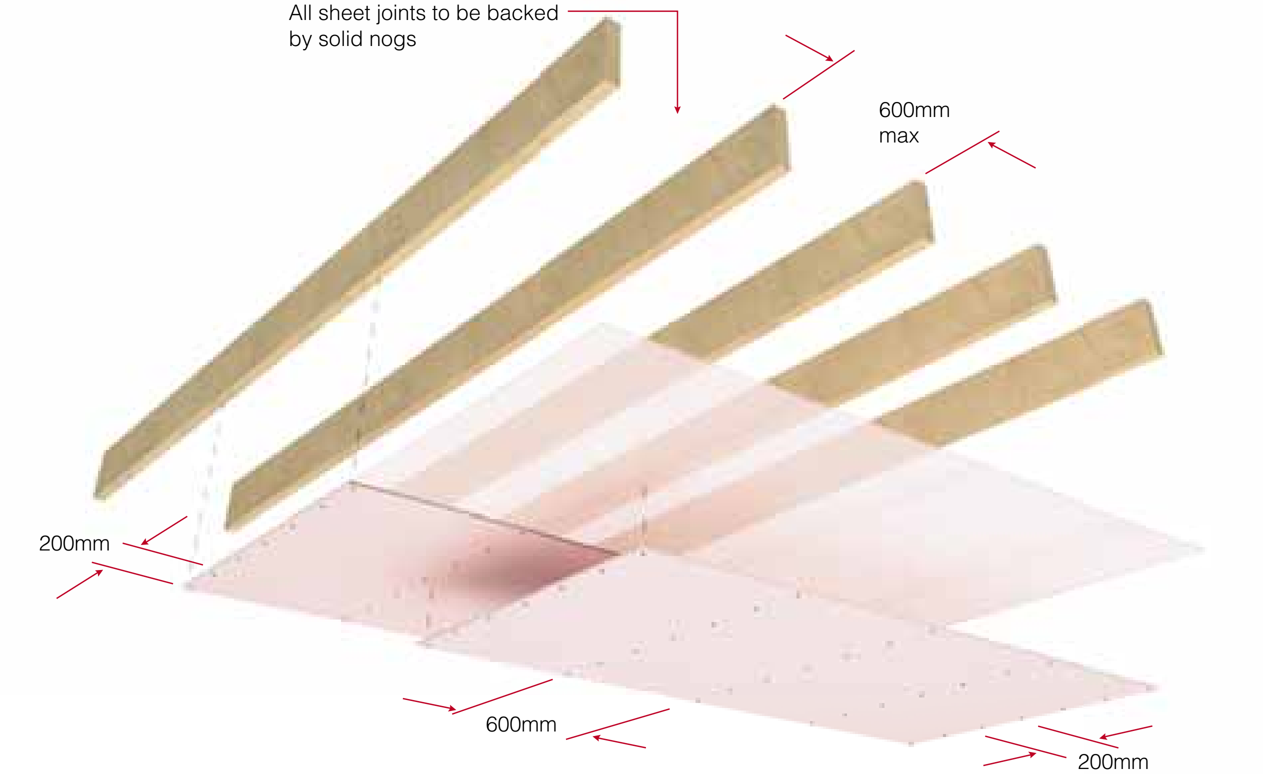
WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls must be protected by GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

INNER LAYER: Unstopped.

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

FOR FURTHER INFORMATION VISIT WWW.GIB.CO.NZ AND SEARCH SPECIFICATION CODE: GBUC 90. ISSUE DATE: JANUARY 2006

Appendix D

GIB® Noise Control Floor/Ceiling Systems

Floor/Ceiling – Timber Joists

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBDFA 60c	LB	56	56	* 72	60/60/60	2 x 13mm GIB Noiseline®

FLOOR FRAMING

Floor joists shall comply with NZS 3604, be spaced at 600mm centres maximum and have a depth of 200mm minimum.

Alternative Floor Framing: Use either Hyspan® or Hybeam® HJ series joists designed for strength and serviceability, no less than 200mm deep and spaced at no more than 600mm. Consult the joist manufacturer regarding construction of the solid blocking contained in the floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be nominal 20mm particle board or minimum 17mm thick structural plywood fixed to the manufacturer's instructions. Nogs are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

GIB QUIET CLIP® AND BATTENS

The GIB Quiet Clip® shall be fastened to the joists at maximum 1200mm centres (and no less than 900mm centres) to support the GIB® Rondo® metal ceiling battens. The battens shall be spaced at 600mm centres maximum.

INSTALLING THE GIB QUIET CLIP®

Use 3 x 32mm x 8g GIB® Grabber® Wafer Head Screws. Insert the first screw into the middle rubber grommet, tighten enough to hold the GIB Quiet Clip® in place, adjust the clip to the correct height, insert the remaining two screws and tighten. Do not over tighten the screws to a point where the grommet is crushed. The screws should be tightened enough to allow the flexibility to remain in the connection between the grommet and the joists.

SOUND CONTROL INFILL

Ceiling overlaid with R1.8 (75mm) Pink® Batts® glasswool insulation.

FASTENING THE LINING

Fasteners

INNER LAYER: 25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.

OUTER LAYER: 41mm x 6g screws as above.

Fastener Centres

200mm centres along each batten and at 100mm along sheet end butt joints. Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required around the ceiling perimeter of the inner layer. The outer lining is then bedded onto the bead.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and the walls are finished with GIB-Cove® adhered with GIB-Cove® Bond or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB Site Guide".

JOINTING

INNER LAYER: Unstopped

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB Site Guide".

* IMPACT INSULATION CLASS (IIC)

A performance of IIC 46 is achieved by a bare floor.

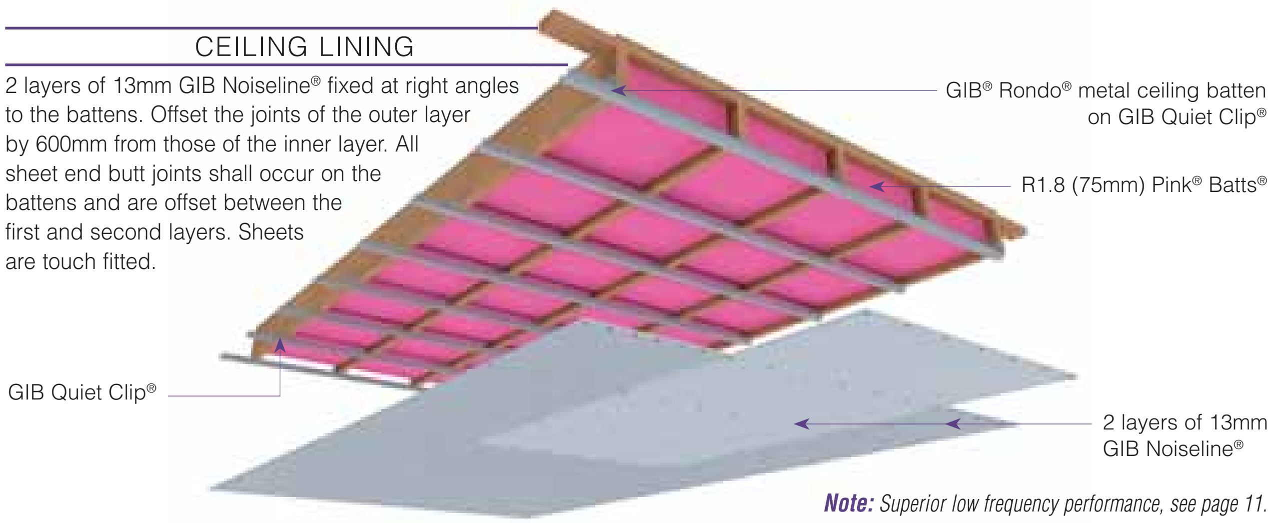
A performance of IIC 50 is achieved with a cushion backed vinyl on particle board on structural plywood.

A performance of IIC 72 is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

Note: *See page 61 for perimeter details .*

CEILING LINING

2 layers of 13mm GIB Noiseline® fixed at right angles to the battens. Offset the joints of the outer layer by 600mm from those of the inner layer. All sheet end butt joints shall occur on the battens and are offset between the first and second layers. Sheets are touch fitted.



Note: *Superior low frequency performance, see page 11.*

In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Floor/Ceiling – Timber Joists

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBDFA 60b	LB	55	55	* 72	60/60/60	2 x 13mm GIB Fyreline®

FLOOR FRAMING

Floor joists shall comply with NZS 3604.
Joists shall be spaced at 600mm centres maximum and shall have a depth of 200mm minimum.
Alternative Floor Framing: Use either Hyspan® or Hybeam® HJ series joists designed for strength and serviceability, no less than 200mm deep and spaced at no more than 600mm. Consult the joist manufacturer regarding construction of the solid blocking contained in the floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturer's instructions. Nogs are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

CEILING BATTEN & DIRECT FIX CLIP SYSTEM

The clips shall be fastened to the joists at 1200mm centres maximum (and no less than 900mm centres) to support the GIB® Rondo® metal ceiling battens or the USG DONN® ScrewFix™ ceiling batten system. The battens shall be spaced at 600mm centres maximum.

SOUND CONTROL INFILL

Ceiling overlaid with R1.8 (75mm) Pink® Batts® glasswool insulation.

CEILING LINING

2 layers of 13mm GIB Fyreline® fixed at right angles to the steel battens. Offset the joints of the outer layer by 600mm from those of the inner layer. All sheet end butt joints shall occur on the battens and are offset between the first and second layers. Sheet joints are touch fitted.

FASTENING THE LINING

Fasteners
INNER LAYER: 25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.
OUTER LAYER: 41mm x 6g screws as above.
Fastener Centres (both layers)
200mm centres along each batten and at 100mm centres along sheet end butt joints. Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required on the inner lining around the ceiling perimeter. The outer lining is then bedded onto the bead.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls are finished with GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

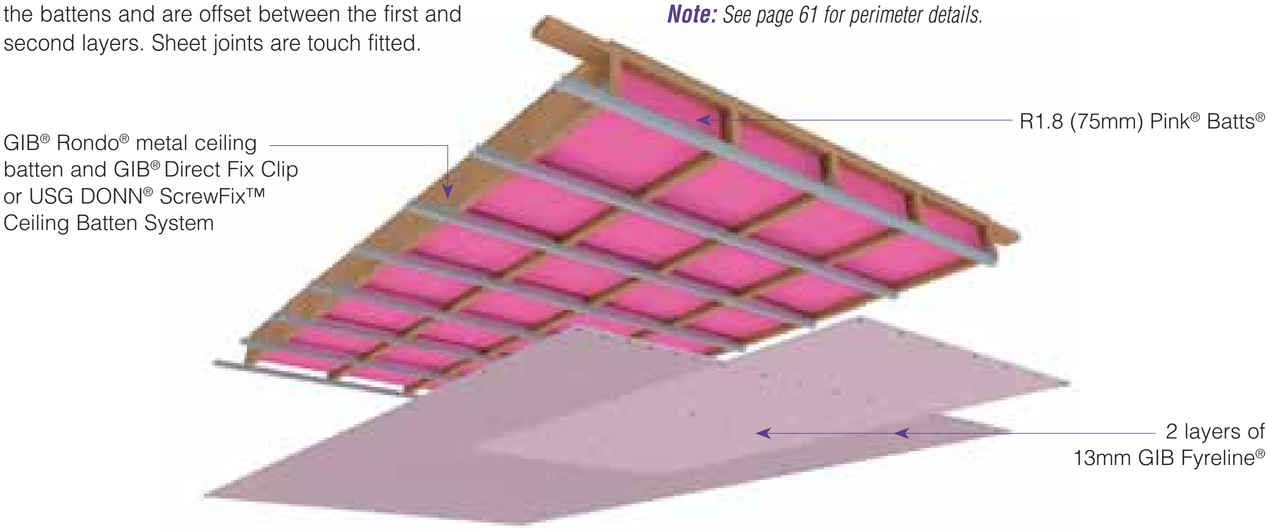
JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

* IMPACT INSULATION CLASS (IIC)

A performance of IIC 46 is achieved by a bare floor.
A performance of IIC 50 is achieved with a cushion backed vinyl on particle board on structural plywood.
A performance of IIC 72 is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

Note: *See page 61 for perimeter details.*



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Floor/Ceiling – Suspended Grid

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBSCA 45	LB	57	57	* 72	45/45/45	2 x 13mm GIB Fyreline®

FLOOR FRAMING

Floor joists shall comply with NZS 3604.
Joists shall be spaced at 600mm centres maximum and shall have a depth of 150mm minimum.

FLOORING

Minimum flooring shall be 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturer's instructions. Nogs are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG DONN® ScrewFix™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting DJ38 strongback channels spaced at 1200mm centres and FC37 furring channels spaced at 600mm centres maximum.
An alternative suspension system with at least equivalent layout, material properties, strength and stiffness may be used.
The suspension system shall be installed in accordance with the manufacturer's instructions.
The cavity depth shall be 275mm minimum (i.e. the distance between the underside of the flooring and the top of the ceiling linings).

SOUND CONTROL INFILL

Ceiling overlaid with R1.8 (75mm) Pink® Batts® glasswool insulation.

CEILING LINING

2 layers of 13mm GIB Fyreline® fixed at right angles to the furring channels. Offset the joints of the outer layer by 600mm from those of the inner layer. All sheet end butt joints must occur on the furring channel with those of the outer layer offset from those of the inner layer. Sheet joints are touch fitted.

FASTENING THE LINING

Fasteners
INNER LAYER: 25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.
OUTER LAYER: 41mm x 6g screws as above.
Fastener Centres (both layers)
200mm centres around the ceiling perimeter and along each furring channel.
100mm centres where sheet end butt joints occur.
Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required on the inner lining around the ceiling perimeter. The outer lining is then bedded onto the bead.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls are finished with GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

* IMPACT INSULATION CLASS (IIC)

A performance of IIC 46 is achieved with a bare floor.
A performance of IIC 47 is achieved with a cushion backed vinyl on particle board or structural plywood.
A performance of IIC 72 is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

Note: *See page 61 for ceiling perimeter details.*

In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Floor/Ceiling – Suspended Grid

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBSCA 60a	LB	58	57	* 72	60/60/60	1 x 13mm GIB Fyreline® and 1 x 16mm GIB Fyreline®

FLOOR FRAMING

Floor joists shall comply with NZS 3604.
Joists shall be spaced at 600mm centres maximum and shall have a depth of 150mm minimum.

FLOORING

Minimum flooring shall be 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturer's instructions. Nogs are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

SUSPENSION SYSTEM

USG DONN® ScrewFix™ steel frame suspension system comprising 2.5mm wire hangers at 1200mm centres supporting DJ38 strongback channels spaced at 1200mm centres and FC37 furring channels spaced at 600mm centres maximum.
An alternative suspension system with at least equivalent layout, material properties, strength and stiffness may be used.
The suspension system shall be installed in accordance with the manufacturer's instructions.
The cavity depth shall be 275mm minimum (i.e. the distance between the underside of the flooring and the top of the ceiling linings).

SOUND CONTROL INFILL

Ceiling overlaid with R1.8 (75mm) Pink® Batts® glasswool insulation.

CEILING LINING

1 layer of 13mm GIB Fyreline® (inner layer) plus 1 layer of 16mm GIB Fyreline® fixed at right angles to the furring channels.
Offset the joints of the outer layer by 600mm from those of the inner layer. All sheet end butt joints must occur on the furring channels with those of the outer layer offset from those of the inner layer. Sheet joints are touch fitted.

FASTENING THE LINING

Fasteners
INNER LAYER: 25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.
OUTER LAYER: 41mm x 6g screws as above.
Fastener Centres (both layers)
200mm centres around the ceiling perimeter and along each furring channel.
100mm centres where sheet end butt joints occur.
Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required on the inner lining around the ceiling perimeter. The outer lining is then bedded onto the bead.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls are finished with GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

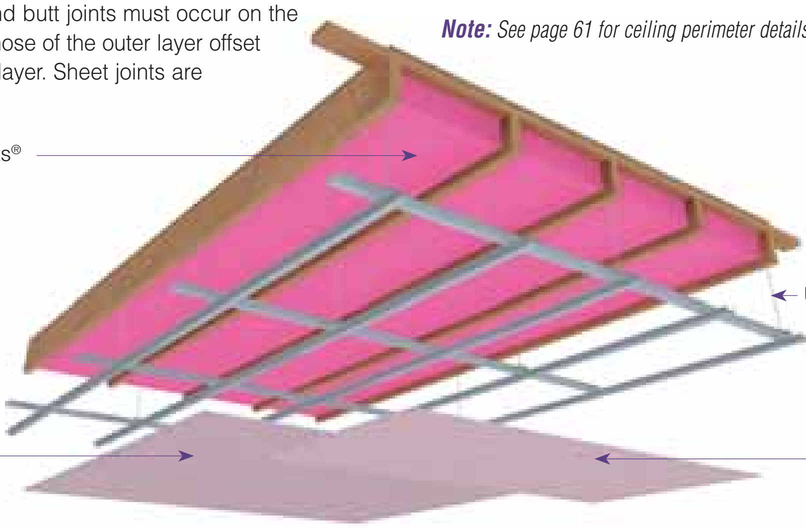
JOINTING

INNER LAYER: Unstopped.
OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

* IMPACT INSULATION CLASS (IIC)

A performance of IIC 46 is achieved with a bare floor.
A performance of IIC 47 is achieved with a cushion backed vinyl on particle board or structural plywood.
A performance of IIC 72 is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

Note: *See page 61 for ceiling perimeter details.*



In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Floor/Ceiling – Timber Joists

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBDFA 30a	LB	52	51	* 71	30/30/30	2 x 13mm GIB® Standard Plasterboard

FLOOR FRAMING

Floor joists shall comply with NZS 3604.
Joists shall be spaced at 600mm centres maximum and shall have a depth of 150mm minimum.
Alternative Floor Framing: Use either Hyspan® or Hybeam® HJ series joists designed for strength and serviceability, no less than 150mm deep and spaced at no more than 600mm. Consult the joist manufacturer regarding construction of the solid blocking contained in the floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be 20mm thick particle board or minimum 17mm thick structural plywood fixed to the joists in accordance with the manufacturer's instructions. Nogs are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

GIB QUIET CLIP® AND BATTENS

The GIB Quiet Clip® shall be fastened to the joists at maximum 1200mm centres (and no less than 900mm centres) to support the GIB® Rondo® metal ceiling battens. The battens shall be spaced at 600mm centres maximum.

INSTALLING THE GIB QUIET CLIP®

Use 3 x 32mm x 8g GIB® Grabber® Wafer Head Screws. Insert the first screw into the middle rubber grommet, tighten enough to hold the GIB Quiet Clip® in place, adjust the clip to the correct height, insert the remaining two screws and tighten.
Do not over tighten the screws to a point where the grommet is crushed. The screws should be tightened enough to allow the flexibility to remain in the connection between the grommet and the joists.

SOUND CONTROL INFILL

Ceiling overlaid with 100mm Pink® Batts® Silencer® glasswool insulation.

CEILING LINING

2 layers of standard 13mm GIB® Plasterboard fixed at right angles to the steel battens.
Offset the joints of the outer layer by 600mm from those of the inner layer.
All sheet end butt joints shall occur on the battens and are offset between the first and second layers.
Sheet joints are touch fitted.

FASTENING THE LINING

Fasteners
INNER LAYER: 25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.
OUTER LAYER: 41mm x 6g screws as above.
Fastener Centres (both layers)
200mm centres along each batten and at 100mm centres along sheet end butt joints.
Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required on the inner lining around the ceiling perimeter.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and walls are finished with GIB-Cove® adhered with GIB-Cove® Bond, or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

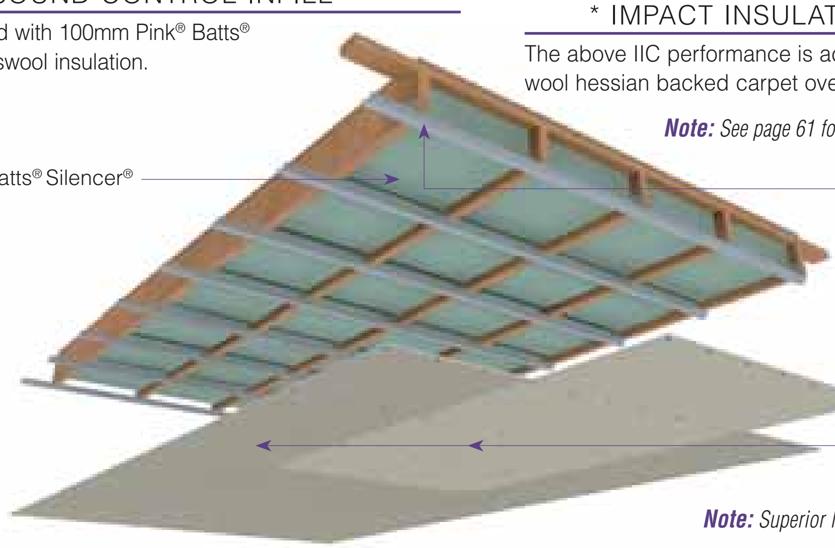
JOINTING

OUTER LAYER: All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

* IMPACT INSULATION CLASS (IIC)

The above IIC performance is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

Note: *See page 61 for perimeter details .*



Note: *Superior low frequency performance, see page 11.*

In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.

Floor/Ceiling – Timber Joists

MARCH 2006

SPEC No.	LOADBEARING CAPACITY	STC	RW	IIC	FIRE RESISTANCE RATING	LINING REQUIREMENTS
GBDFA 30d	LB	51	51	* 68	#	1 x 13mm GIB Noiseline®

FLOOR FRAMING

Floor joists shall comply with NZS 3604, be spaced at 600mm centres maximum and have a depth of 200mm minimum.

Alternative Floor Framing

Use either Hyspan® or Hybeam® HJ series joists designed for strength and serviceability, no less than 150mm deep and spaced at no more than 600mm. Consult the joist manufacturer regarding construction of the solid blocking contained in the floor/ceiling to wall junctions.

FLOORING

Minimum flooring shall be nominal 20mm particle board or minimum 17mm thick structural plywood fixed to the manufacturer's instructions. Nogs of a minimum of 100 x 50mm are required behind sheet joints. If tongue and groove flooring is used verification of performance must be obtained from the supplier of the flooring system.

GIB QUIET CLIP® AND BATTENS

The GIB Quiet Clip® shall be fastened to the joists at maximum 1200mm centres (and no less than 900mm centres) to support the GIB® Rondo® metal ceiling battens. The battens shall be spaced at 600mm centres maximum.

INSTALLING THE GIB QUIET CLIP®

Use 3 x 32mm x 8g GIB® Grabber® Wafer Head Screws. Insert the first screw into the middle rubber grommet, tighten enough to hold the GIB Quiet Clip® in place, adjust the clip to the correct height, insert the remaining two screws and tighten. Do not over tighten the screws to a point where the grommet is crushed. The screws should be tightened enough to allow the flexibility to remain in the connection between the grommet and the joists.

SOUND CONTROL INFILL

Ceiling overlaid with 100mm Pink® Batts® Silencer® glasswool insulation.

CEILING LINING

1 layer of 13mm GIB Noiseline® fixed at right angles to the battens. All sheet end butt joints shall occur on the battens. Sheet joints are touch fitted. Where a fire resistance rating is required all joints must be back-blocked in accordance with the publication entitled "GIB® Site Guide".

*#**Note:** If a Fire Resistance Rating is required, refer GBSC 30 in the publication "GIB® Fire Rated Systems".*

FASTENING THE LINING

Fasteners

25mm x 6g GIB® Grabber® Self Tapping Drywall Screws.

Fasteners Centres

200mm centres along each batten and 100mm centres along sheet end butt joints. Place fasteners no closer than 12mm to the sheet edges.

ACOUSTIC SEALANT

A bead of GIB Soundseal® acoustic sealant is required around the ceiling perimeter.

WALL/CEILING JUNCTIONS

The internal angle between the ceiling and the walls are finished with GIB-Cove® adhered with GIB-Cove® Bond or boxed corners (square stopped) filled and taped in accordance with the publication entitled "GIB® Site Guide".

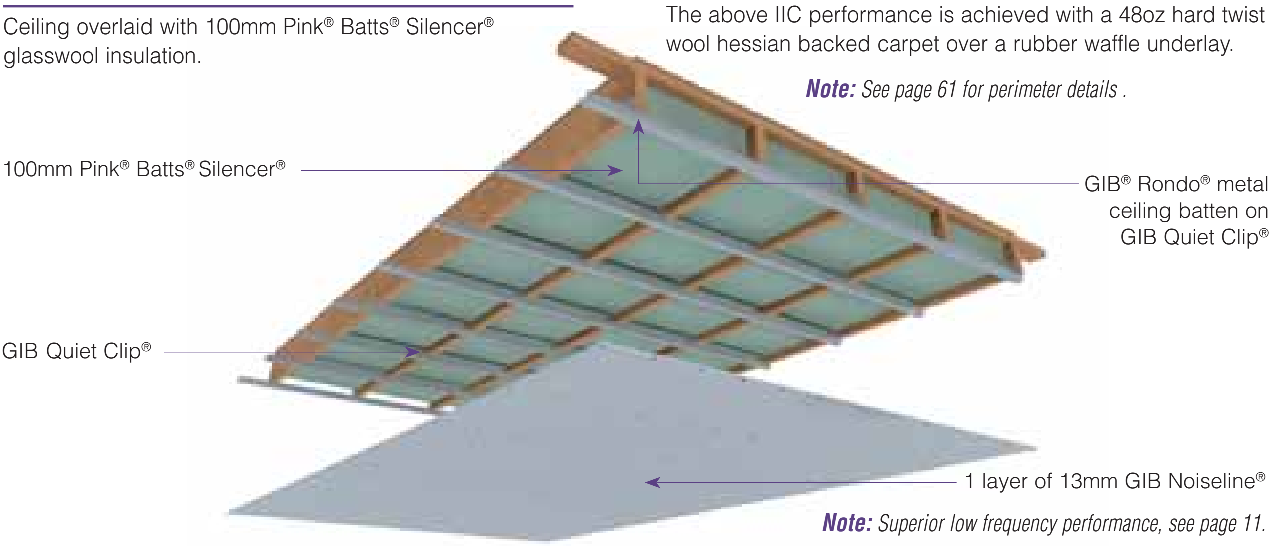
JOINTING

All fastener heads stopped and all sheet joints tape reinforced and stopped in accordance with the publication entitled "GIB® Site Guide".

* IMPACT INSULATION CLASS (IIC)

The above IIC performance is achieved with a 48oz hard twist wool hessian backed carpet over a rubber waffle underlay.

***Note:** See page 61 for perimeter details .*



***Note:** Superior low frequency performance, see page 11.*

In order for GIB® systems to perform as tested, all components must be installed exactly as prescribed. Substituting components produces an entirely different system and may seriously compromise performance. Follow system specifications.